CITY OF MORRO BAY

ENVIRONMENTALLY SENSITIVE HABITAT AREA (ESHA) ANALYSIS: 2050 SEA LEVEL RISE SCENARIO

Plan
MORRO BAY

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1. INTRODUCTION

1.1 PURPOSE

Rincon Consultants, Inc. (Rincon), in cooperation with Michael Baker International (MBI), is assisting the City of Morro Bay (City) in analyzing the potential future effects to environmentally sensitive habitat areas (ESHAs) resulting from climate change and associated sea level rise. This exercise includes a projection of future effects of sea level rise and associated coastal flooding and erosion events on ESHAs within the Morro Bay coastal zone, based on hazard analysis and sea level rise analysis completed by Moffat and Nichol, existing sea level rise models for the region, and the current location and extent of ESHAs in the City. As part of this effort, Rincon has developed a forward-thinking ESHA Geographic Information Systems (GIS) map layer that identifies ESHAs particularly vulnerable to the effects of climate change. Although this component is advisory rather than regulatory, it will provide the City with decision-making capabilities based on the best available understanding of likely future conditions and aids in identifying habitats, including the estuary, foredune, and backdune communities, that are particularly vulnerable.

This report provides a brief description of the physical effects of sea level rise on the coastal zone, a summary of the methodology used to develop the forward-looking ESHA map layer described above, a description of ESHAs that occur within the Morro Bay coastal zone and their susceptibility to effects of sea level rise, and a summary of the potential effects sea level rise could have on the ESHAs within the Morro Bay coastal zone. Figure 1 illustrates the location of the coastal zone within and adjacent to the City.

1.2 CALIFORNIA COASTAL COMMISSION SEA LEVEL RISE POLICY GUIDANCE

The California Coastal Commission (CCC) adopted a guidance document on August 12, 2015 entitled *California Coastal Commission Sea Level Rise Policy Guidance: Interpretive Guidelines for Addressing Sea Level Rise in Local Coastal Programs and Coastal Development Permits ("Sea Level Rise Policy Guidance")*. This advisory document focuses on the application of the Coastal Act to situations influenced or caused by sea level rise. The Coastal Act addresses sea level rise through policy outlined in Local Coastal Program (LCP) certifications and updates and through Coastal Development Permit (CDP) decisions. The guidance document presents current science, technical, and other information and practices intended to guide LCP planning and development decisions toward effective coastal management actions (CCC 2015).

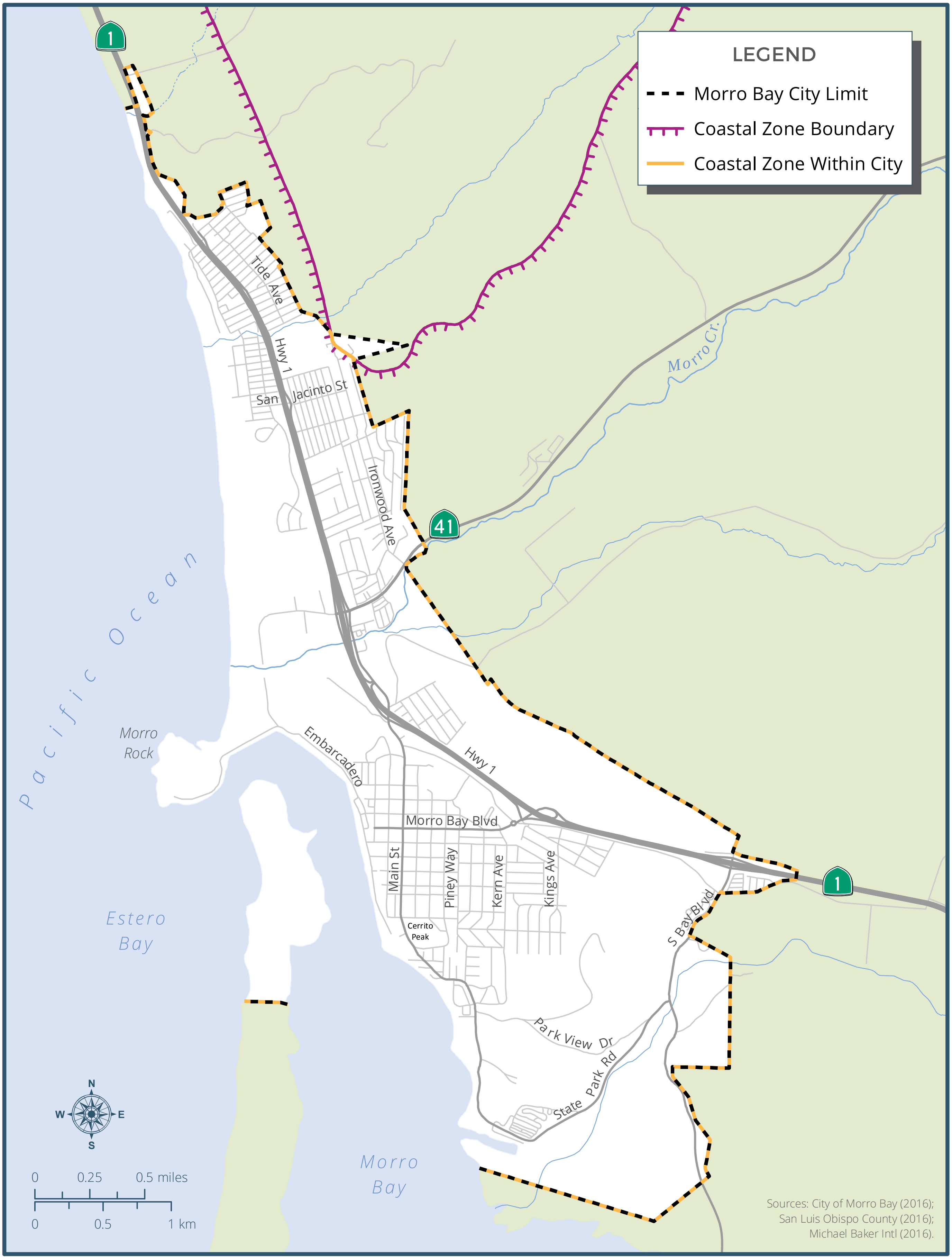

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FIGURE 1

City of Morro Bay Coastal Zone Area

Although the policy guidance document is advisory and does not alter or supersede existing legal requirements, it outlines fundamental principles for addressing sea level rise in the coastal zone and is a useful tool to aid in updating LCPs with consideration for hazard management and potential effects of adaptation strategies on existing coastal resources. The fundamental principles in this guidance broadly form four categories: use science to guide decisions; minimize coastal hazards through planning and development standards; maximize protection of public access, recreation, and sensitive coastal resources; and maximize agency coordination and public participation. The CCC uses these principles to provide information and guidance regarding the science of sea level rise; consequences of sea level rise for communities, coastal resources, and development; suggestions for addressing sea level rise in local coastal programs and coastal development permits; and finally, adaptation strategies to manage sea level rise.

This report is focused on effects of sea level rise on sensitive coastal resources, specifically ESHAs, and the approach has been informed by the guidance document.

2. METHODOLOGY

To evaluate potential effects of sea level rise on ESHAs in the Morro Bay coastal zone, Rincon analyzed existing datasets and sea level rise hazard projections as follows. Rincon previously produced a baseline report that identified the presence of several types of ESHAs in the Morro Bay coastal zone, and mapped estimated current extent (as of 2017) using existing published datasets, reconnaissance-level surveys, and aerial photograph interpretation. Rincon utilized the baseline ESHA report, *ESHA Review and Current Conditions Mapping Report* (Rincon Consultants, Inc. 2018), as the starting point for analysis of potential sea level rise effects. Next, a literature review was completed to compile existing scientific knowledge regarding mechanisms through which sea level rise affects habitat types that comprise ESHAs in the City. Rincon also reviewed publications regarding projected sea level rise along the California coast, the hazards analysis completed by Moffatt and Nichol for the City as part of the *City of Morro Bay Community Baseline Assessment* (Michael Baker International 2017), and the additional analysis presented in the *Sea Level Rise Adaption Strategy Report* by Moffatt and Nichol ("*Adaptation Strategy Report*"; 2018) to identify areas vulnerable to sea level rise and evaluate in conceptual terms the potential effects of sea level rise on ESHAs in the City.

Additionally, using the existing baseline ESHA dataset, elevation data, sea level rise predictions, and the vulnerable locations identified in the *Adaptation Strategy Report*, Rincon also generated a map layer depicting projected sea level rise effects on ESHAs using predicted sea level rise in 2050. This forward-looking map layer considers areas vulnerable to the effects of projected sea level rise due to changing water levels and associated erosion and flooding on ESHAs within the coastal zone of Morro Bay.

3. EXISTING DATA

The CCC guidance recommends that science should be used to guide decisions, and that the best available science for locally relevant (context-specific) sea level rise projections should be used for coastal planning and permitting. In keeping with this guidance, a review of existing scientific publications, models, maps and other spatial datasets, and existing planning documents form an important component of this study. The following sections identify these data sources, and summarize pertinent information that support our analysis of sea level rise effects to ESHAs.

3.1 BASELINE ESHA CONDITION

Within the City's coastal zone, approximately 1,099 acres of mapped potential ESHA were identified. ESHAs were grouped into three general habitat communities/categories: aquatic resources and wetland habitat; other sensitive natural communities; and breeding and overwintering sites. Within these broad habitat categories, more detailed community data (such as coastal strand, dune scrub, river/stream and monarch overwintering roosts, etc.) were included.

Current ESHA determinations (as mapped in 2017) are outlined in Table 1 below. Full descriptions of each ESHA determination can be found in the previously submitted *ESHA Review and Current Conditions Mapping Report* prepared by Rincon (2017), and mapped extent of these ESHA types are depicted in Figure 7 of the previously submitted *ESHA Review and Current Conditions Mapping Report*.

Table 1. Baseline ESHA Categories (2017 Map Set)

ESHA Category	Brief Description
Aquatic resources and wetland habitats These include streams, riparian areas, both freshwater and brackish wetlands, tidal channels and mudflats:	
Freshwater Streams and Riparian Areas	
Rivers and Streams	Several creeks and their tributaries flow through the City and terminate into the Morro Bay estuary or directly into the Pacific Ocean within the City's coastal zone. Morro Creek and Toro Creek form seasonal sand bars at the mouth of the streams that block direct flow to the sea during summer months, creating a lagoon between the river mouth and the Pacific Ocean. Ephemeral streams are included in this type.

ESHA Category	Brief Description
Willow Woodland and Willow Scrub	Willow woodland and scrub habitats are areas in which woody riparian vegetation dominates and forms dense thickets or woodlands. These habitats are commonly associated with floodplains and banks. Arroyo willow (*Salix lasiolepis*) is a common species in these types.
Wetlands	
Estuarine Wetlands, Coastal Salt Marsh, and Pickleweed Mat	The delta formed at the mouths of Chorro and Los Osos creeks forms an estuarine wetland primarily vegetated with pickleweed (*Salicornia pacifica*; also called *Sarcocornia pacifica* in some references) mat wetland. These tidally influenced wetlands have saline soils due to the tidal waters. Other brackish and salt marsh habitats are also present, including areas that provide suitable habitat for the endangered California seablite, a vascular plant that colonizes the upper portion of the intertidal zone and slight elevations above high tide.
Freshwater Emergent Wetlands	Multiple freshwater emergent wetlands are located within the Morro Bay coastal zone. These areas are dominated by wetland vegetation such as dock, brown headed rush, and tule (*Schoenoplectus acutus*). Freshwater emergent wetlands are found both at springs and seasonal drainages and provide habitat for avian and special status plant species. Some of these wetlands also include areas of California red-legged frog critical habitat.
Dune wetlands	Dune wetlands often occur where fresh water from rivers or streams accumulates behind a sandbar at the mouth of a coastal stream, or where perched groundwater accumulates in low lying backdune areas. The soils in these areas have slow drainage and form mesic environments with nutrient rich soils and high potential to support wetland vegetation.
Estuary and Shallow Bay	
Shallow Bay, Mudflat and Eelgrass Habitat	The shallows of Morro Bay and the associated estuary consist of a varying degree of brackish water. These waters are a mixture of tidal waters of the Pacific Ocean and freshwaters from surrounding watersheds. These waters provide nesting and foraging habitat for many bird species in the area, as well as abundant fish habitat. This ESHA also supports the threatened populations of eelgrass. This ESHA type includes those areas not vegetated with estuarine marsh vegetation.
Tidal Channels	At the mouth of the major streams, larger tidal channels are evident and interspersed with coastal salt marsh (identified above). The majority of these channels have unvegetated beds and are largely exposed at low tide, allowing foraging habitat for coastal bird species and other wildlife.
Other Sensitive Natural Communities There are variety of terrestrial sensitive natural communities present within the City's coastal zone that provide essential habitat for many sensitive species, including areas that overlap in part with critical habitats for western snowy plover and Morro shoulderband snail.	
Foredune	The foredune natural community occurs where sand begins to accumulate and stabilize, with increased plant cover and diversity. Most of this ESHA overlaps with the western snowy plover critical habitat, provides essential habitat for other special status species, such as legless lizard (*Anniella pulchra*), and contains suitable habitat for several special status plant species.

ESHA Category	Brief Description
Backdune and Stabilized Dune with Dune Scrub	The stabilized dune and backdune natural community contains an increased abundance of herbaceous and woody vegetation. Dune scrub communities occur in stabilized coastal dune areas with higher water retention, more organic matter, and less salt (Sims 2010). Dune scrub ESHA contains regions of the western snowy plover and Morro shoulderband snail critical habitats, and provides abundant nesting and foraging habitat for other avian and special status wildlife species. This community also provides suitable habitat for many special status plant species.
Coastal Bluff Scrub	Coastal bluffs are present at the transition between the coastal strand and dune communities to upland terraces. Vegetation in this community is adapted to strong winds, salt spray and thin soils. Coastal bluff provides an important transition between coastal strand and dune, and upland inland habitats. Some areas are degraded with presence and dominance of invasive plant species.
Black Hill Natural Area	Black Hill supports a mixture of coastal sage scrub, chaparral, and annual and native grassland communities with scenic views over the estuary and south bay. The dominant community is coastal sage scrub. The site provides habitat for a variety of native birds, other wildlife, and rare plants.
Breeding and Overwintering Sites These are ESHAs that are not formed from sensitive vegetation communities but provide important communal roost and breeding habitat for falcons, egrets, herons, and cormorants, and overwintering habitat for monarch butterfly. These areas are typically re-used for many years and are essential for the survival and reproduction of certain species.	
Morro Rock	Morro Rock is a known peregrine falcon nest site.
Monarch Overwintering Sites	Monarch overwintering roosts in groves are scattered throughout the coastal zone of Morro Bay
Rookeries/ communal breeding sites	A known former heron, egret and cormorant rookery, now occupied primarily by cormorants, is located at Fairbanks Point. In 2017, heron and egret rookeries were located at Bayshore Park in eucalyptus and Monterey cypress trees, and in cypress and eucalyptus trees along Embarcadero in front of the former power plant.

3.2 SEA LEVEL RISE PROJECTIONS

As part of the City's *Community Baseline Assessment*, Moffat and Nichol used sea level rise projection models from the National Research Council's *Sea-Level Rise for the Coasts of California, Oregon, and Washington* (NRC 2012) to evaluate coastal hazards. Moffat and Nichol also used these sea level rise projection models and the hazard zones derived from them in the *Sea Level Rise Adaptation Strategy Report* for the City of Morro Bay (2018). Table 2 shows the projected sea level rise, low and high range, and uncertainty for this area of the California, using this 2012 model.

Table 2. Sea Level Rise Projections*

Projection Year	Projected Sea Level Rise (ft)	Projection uncertainty (ft, +/-)	Low Range (ft)	High Range (ft)
2050	0.9	0.3	0.4	2.0
* Based on NRC 2012, as described in Moffat and Nichol 2018				

The 2015 *Sea Level Rise Policy Guidance* document identified the 2012 NRC model as the best available model for California at the time this guidance was finalized. The guidance also indicates that additional, locally relevant, peer-reviewed documents representing best available science should also be used when possible. Moffat and Nichol also considered information in the recent study titled *Rising Seas in California – An Update on Sea-Level Rise Science* (OPC-SAT 2017) for the State of California, which presents similar sea level rise projections to the range presented in the 2012 NRC model for the year 2050 and higher sea level rise by 2100 than the NRC model. Moffat and Nichol also point out that the OPC-SAT 2017 model does not include recent extreme polar ice loss scenarios which could further alter projections and the probabilities of the degree of sea level rise.

The analysis in this ESHA report is based upon the 2012 NRC model used by Moffat and Nichol to develop a model of resultant coastal hazards in the year 2050, which also supported the *Sea Level Rise Adaptation Strategy Report* (2018), but it should be noted that the exact timeframe and degree of sea level rise are not known and other sea level rise projections indicate the possibility that greater effects could occur.

3.3 SEA LEVEL RISE HAZARDS ANALYSIS AND ADAPTION STRATEGY REPORT

As part of the City's *Community Baseline Assessment*, Moffat and Nichol evaluated coastal hazards that could result from sea level rise (2017). The report identifies four categories of hazards that could result from sea level rise, and modeled the areal extent over which these hazards are likely to occur, based on the 2050 sea level rise projection. These categories were also used to support Moffat and Nichol's *Sea Level Rise Adaptation Strategy Report* (2018) and are as follows:

- Inundation Hazard Zone: Areas within this zone would be subject to daily wetting and drying associated with tides. A mean high water tide elevation and the 2012 NRC high value for sea level rise in 2050 were used to model the future inundation hazard zone.

- Flood Hazard Zone: Areas within this zone are above the daily inundation hazard zone, and would be subject to short duration inundation events associated with extreme waves or large precipitation events. The upper limit of this zone represents the water level associated with a 100-year event (storm or wave) plus the 2012 NRC high value for sea level rise in 2050. Modelling used to generate this zone incorporated a future equilibrium position of the shoreline due to projected changes resulting from sea level rise and resultant shoreline evolution.

- Bluff Hazard Zone: Rising sea levels expose coastal bluffs to more frequent wave action, and this can result in increased bluff erosion. This zone represents the area between the current bluff edge, and the projected future bluff edge resulting from the composite action of a 100-year wave event plus the 2012 NRC high value for sea level rise in 2050.

- Dune Hazard Zone: Sea level rise can result in erosion of dunes, causing a landward migration of the dune inward. This zone represents the area between current dune toe (outermost edge to the coastal side) and projected future dune toe resulting from the composite action of a 100-year wave event plus the 2012 NRC high value for sea level rise in 2050.

These hazard zones are depicted over aerial imagery as Figure 2. Because effects of sea level rise are partially tied to landscape position and adjacent topography, an elevation dataset was also considered in this evaluation, and is presented as Figure 3.

Additionally, in the *Adaption Strategy Report* which assessed the vulnerability of the Morro Bay coastal zone to sea level rise (January 2018), Moffat and Nichol identified potential future adaptation strategies to accommodate effects of sea level rise on existing infrastructure and resources. This study determined that the most vulnerable coastal resources in the City during the year 2050 timeframe were beaches, state parks, coastal parcels and transportation infrastructure.

Three adaption strategies for responding to sea level rise are protection, accommodation, and retreat. Protection strategies refer to those strategies that employ some sort of engineered structure or other measure to defend development (or other resources) in its current location without changes to the development itself. Accommodation strategies refer to those strategies that employ methods that modify existing developments or design new developments to decrease hazard risks and thus increase the resiliency of development to the impacts of sea level rise. Flood-proofing and relocation of vulnerable utilities to higher elevation are examples of accommodation. Retreat strategies are those strategies that relocate or remove existing development out of hazard areas and limit the construction of new development in vulnerable areas. These strategies include land use designations and zoning ordinances that encourage building in more resilient areas or gradually removing and relocating existing development.

The *Adaption Strategy Report* focused on providing adaptation strategies for three at-risk areas of the Morro Bay coastal zone: Highway 1, Morro Rock Parking Lot, and the Embarcadero. At these locations, the report analyzed the physical effects of sea level rise, and presented conceptual adaption strategies to mitigate for sea level rise effects. As discussed in the study, certain adaptation strategies can have impacts on natural resources including ESHA. For instance, protection techniques that rely on hard armoring approaches can preclude migration of certain habitat types, such as dunes, landward. Some strategies incorporate habitat elements and can at least temporarily lessen effects on resources, such as soft armoring techniques in which dune creation is incorporated into the protection technique. In some cases doing nothing also impacts natural resources by exacerbating conditions that create risk for the resource, such as not relocating vulnerable utilities above high water, posing a risk for leaks and spills. Retreat of structures and facilities can also provide opportunities for habitat retreat, though this is dependent on topography and conditions at the specific location.

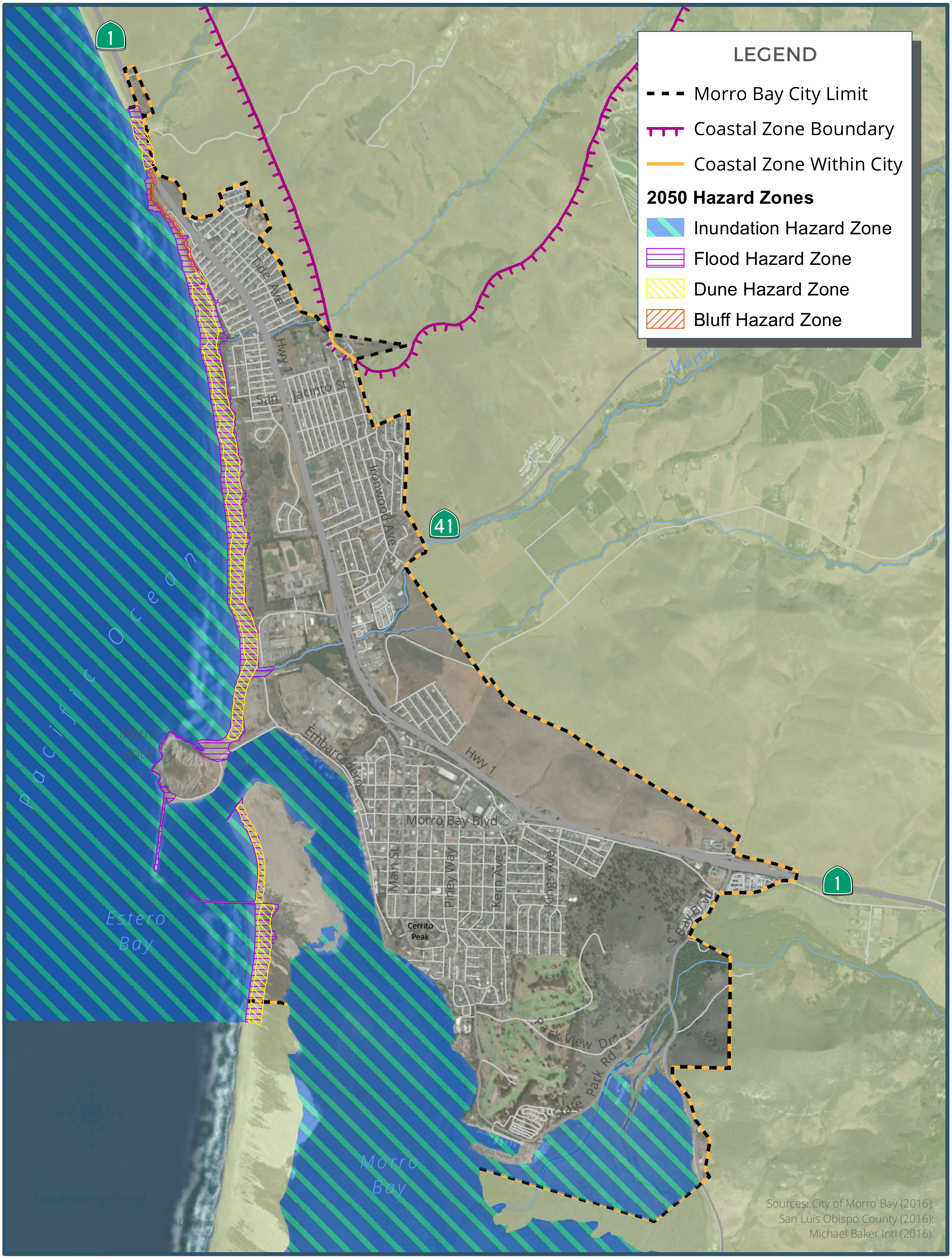

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FIGURE 2

Sea Level Rise Projections and Associated Hazards for the Year 2050

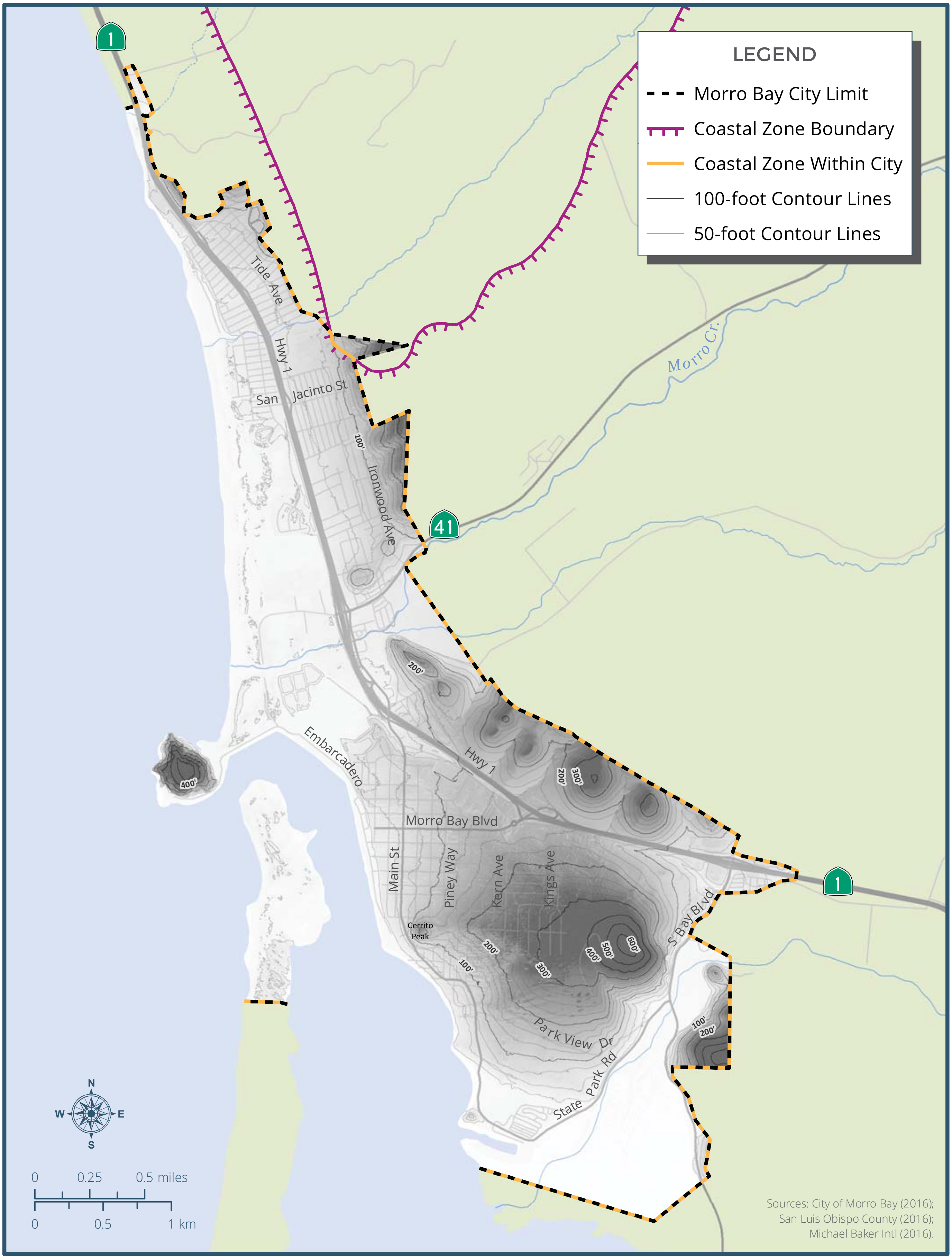

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FIGURE 3

City of Morro Bay Elevation Data

3.4 HABITAT EFFECTS OF SEA LEVEL RISE

Rincon conducted a literature review to evaluate the findings of studies pertaining to the effects of sea level rise on habitats and vegetation communities comparable to those found in the coastal zone of Morro Bay, including eelgrass beds, pickleweed marsh, coastal estuary, and coastal dune communities. The literature review considered information from west coast studies, restoration projects, and monitoring reports related to coastal ecosystems, but also incorporated studies and technical reports from similar habitats nationally and worldwide. These sources document common mechanisms through which sea level rise impacts and alters coastal habitats and/or discuss other stressors that are also impacting these systems, which could be exacerbated by stressors resulting from sea level rise. A full list of sources reviewed is included in Section 7.

According to the CCC *Sea Level Rise Policy Guidance*, the main physical effects of sea level rise include flooding, inundation, wave impacts, coastal erosion, changes in sediment dynamics, and saltwater intrusion (2015). These factors in turn alter environmental conditions and create stress on existing habitats. As sea level rise progresses, conditions can become unsuitable for the previous habitat type, and the area converts to a different habitat condition. Habitat effects of sea level rise are influenced by the rate of sea level rise/ tidal change, and rates of sedimentation and erosion, and can be exacerbated by other stressors on a system, such as excess nutrient inputs, invasive species, and hydromodification.

Additionally, the different disruptive effects resulting from sea level rise can interact. For instance, the same area may be susceptible to inundation, flooding, and erosive effects: inundation may result in reduced vegetation cover, creating vulnerability to more rapid erosion, and intensification of flood events may further accelerate erosion. Accelerated erosive processes can affect sedimentation and the rate of coastal zone accretion. Accretion refers to the rate at which sediment can be deposited within a habitat, modifying the shoreline, altering the equilibrium position, and partially offsetting erosive forces. Changed rates of erosion, sedimentation, and accretion affect the adaptive capacity of the coastal habitats, and can support retreat and reformation of certain habitat types landward of their current extent in some situations (Beller et al. 2013; San Francisco Bay Conservation and Development Commission [BCDC] et al. 2013).

Sea level rise effects on coastal ecosystems can result in habitat migration/retreat and habitat type conversion and loss without replacement:

- **Habitat Migration/Retreat:** Habitat migration/retreat occurs when a community is able to expand into adjacent areas with suitable elevations and soils in response to environmental pressures and changing conditions in the originally occupied areas. Habitat migration is successful when migration occurs at a rate greater than or equal to that of sea level rise, which requires new areas to be available and become suitable for the retreating habitat at the same rate or faster than the existing location becomes unsuitable.

- **Habitat Conversion/Loss:** When a habitat cannot migrate at a suitable rate, the species composition of the habitat may change to accommodate the inundation of water. Species commonly found in the lowest elevational ranges of the habitat, and more adapted to flooding and inundation of sea water, may become the dominant plant species in the habitat. This effectively converts the habitat to a species composition suitable for higher water levels. Where substantial constraints such abrupt topographic changes, revetments and developed areas, exist at the landward edge of the coastal ecosystems, rising sea levels "squeeze" these ecosystems into narrower bands, resulting in a net loss of cover of certain types.

Key mechanisms of sea level rise impacts on coastal habitats resulting from the primary coastal hazards are summarized in the following subsections.

3.4.1 Inundation Effects

Sea level rise results in increased depth, duration, and frequency of inundation in ecosystems along the immediate coast, stressing vegetation that is not adapted to frequent inundation, and altering soil and water chemistry (BCDC et al. 2013). Coastal marsh systems vary along a gradient influenced by topographic position, proportion of freshwater and saltwater influences, and typical tidal processes and elevations. Several sources cite concerns that inundation effects will ultimately result in loss of existing coastal marsh by drowning the vegetation currently occupying these habitats (e.g. Beller et al. 2013; BCDC et al. 2013; USGS 2016; CCC 2016).

Sea level rise contributes to changes in the extent of areas regularly inundated at high tide, changing water chemistry and resulting in changes in vegetation. Areas that were previously slightly elevated above daily tidal inundation levels become regularly inundated. The tidal-terrestrial habitat transition zone moves landward and water height above low marsh areas increases during periods of inundation. Increased inundation can also exacerbate erosion, as stressed and dying vegetation is less effective at holding soil in place and trapping new sediment, reducing accretion rates (BCDC et al. 2013).

Pickleweed marshes typically occur between mean high water to the highest high tide line (areas inundated in extreme events) and pickleweed tends not to persist in areas of prolonged flooding or extended inundation (multiple papers, as cited in Griffith 2010). Increased submergence time is correlated with die-off of pickleweed, resulting in reduced cover and eventual transition to mudflat or open water (Griffith 2010). Subsidence can also exacerbate increases in submergence time.

With increased tidal inundation, tidal low marsh may convert to mudflat, and areas previously occupied with high marsh species transition to low marsh. With further intrusion of saline water landward as a result of changed inundation patterns, areas previously vegetated with freshwater marsh and riparian species may transition to more salt tolerant types. Many areas of the California coast lack space for the marsh to retreat as inundation extent changes with sea level rise due to adjacent topographic constraints (hills and bluffs) or shoreline armoring, and as a result, sea level rise is anticipated to result in net loss of coastal salt marsh habitat and a narrowing of the tidal-terrestrial transition zone (Beller et al. 2013; BCDC et al. 2013; USGS 2016).

Changes to inundation extent also have implications for brackish lagoons that form at the mouths of certain freshwater streams during summer months (Behrens et al. 2015). These lagoons typically form through sandbar formation at the mouth of the creek during the dry season when outflow is at a minimum, and these can serve as important breeding and/or rearing habitat for fish, including tidewater goby and juvenile steelhead. Exposure to daily tidal inundation would alter the water chemistry due to tidal influences further up channel, and changes to water movement and deposition patterns would potentially alter sand bar formation. Recent modeling of coastal erosion suggests accelerated loss of beaches, with complete erosion of between 31 and 67 percent of southern California beaches predicted by 2100) (Vitousek et al. 2017). The projected loss of sandy beach through erosion could further alter bar formation by removing a sand source, and erosion or landward migration of sand spits and barrier bars is expected to become more frequent with sea level rise (NRC 2012). As a result of changes to sandbar dynamics and water level, these lagoons may be eliminated, or they may migrate further upstream due to further intrusion of sea water, and differences in channel geometry upstream of the stream mouth could dictate a smaller lagoon feature compared with current conditions. These features may also be susceptible to more frequent flooding, when high water conditions prevent outflow from the mouth of the stream. The outcome for a specific site depends on site-specific conditions, including shoreline shape, current and tidal patterns, sediment and sand sources and transport dynamics.

Additionally, the CCC policy guidance identifies eelgrass beds and rocky intertidal areas as potentially susceptible to sea level rise. A change in the extent of inundation and increased water height could reduce or eliminate exposure of rocky intertidal areas during typical tidally cycles. Changes to inundation patterns would change water chemistry and sediment patterns and may affect distribution of suitable habitat for eelgrass (Short and Neckles 1998). In areas with steep bathymetric changes, increases in water height and extent of inundation could render certain eelgrass beds unsuitable. Conversely, in areas with gentle bathymetry some areas that were marginally suitable and/or not occupied due to exposure and desiccation at lowest tides may have small gains in potentially suitable area, where increased inundation and water height reduce drying effects, but such gains in potential habitat would be modest and may be offset by areas in which deeper water heights and steep bathymetric changes cause habitat to become unsuitable over very short distances (Palacios 2010; Shaughnessy et al 2012). Changes to inundation patterns are also anticipated to modify sediment conditions and could affect clarify, potentially affecting eelgrass distribution. It should be noted that water level is one of several factors associated with eelgrass distribution, and nutrient loads, water clarity, sediment types, and pathogens also exert an influence (Palacios 2010; Morro Bay National Estuary Program [MBNEP] 2017).

3.4.2 Flooding Effects

Changes to flooding patterns as a result of sea level rise will increase the areas of both terrestrial and aquatic habitats that are inundated during flood events, including wave action events, storm-related events, and combinations of both (USGS 2016; CCC 2016). Effects on habitat depend partially on the duration for which the area is flooded. Many plants can tolerate infrequent flooding of short duration of a few hours to days, and recover when floodwaters recede. However, more prolonged flooding can cause the death of terrestrial plants, and recovery requires germination and growth of new individuals. For perennial species, the time to maturity can be years.

Flooding caused by wave action could also result in changes to soil and water chemistry due to more frequent introductions of saltwater, altering the habitat suitability and stressing existing plant life. If floods become more frequent or extreme, areas in flood zones are likely to see transitions in habitat and vegetation communities. Flooding may also alter water depth, chemistry, and aeration conditions in small lagoons formed at the mouth of freshwater creeks.

Flooding of terrestrial habitats makes these areas temporarily unavailable to terrestrial wildlife for breeding, and foraging and refuge opportunities may be reduced depending on the magnitude and duration of the flood event. Additionally, flooding can exacerbate erosion hazards, which are discussed in the following sections.

3.4.3 Dune Erosion Effects

Dune erosion is anticipated to alter the size and shape of existing coastal dune systems (NRC 2012). In turn, this process would result in changes to the type and distribution of vegetation and habitat niches (Feagin et al 2005; Garner et al 2015). As the dune erodes, the dune material would be carried away and redeposited by wind and water, altering the shape of the coastal strand and dune system. In some circumstances, dunes can migrate landward as erosive processes reshape the dune and adjoining bluffs, redistributing material and changing the surface topography. However, where dunes are bordered to the landward side by structures or revetments, landward migration is not possible (NRC 2012). Foredunes are particularly vulnerable to rapid erosion with large wave events, flooding and high tides.

Vegetation on dunes plays a key role in dune maintenance, because plants catch and settle blowing sand. Foredune species are adapted to survive blowing, shifting sands and burial, and can build dunes through slowing the movement of dune particles (Miller 2015). Backdunes are typically more stable and have larger, woody vegetation that further stabilizes the movement of sand. Dune elevation is a contributing factor in vegetation patterns on dunes, particularly in foredune and interdune areas (Miller 2015). However, when dune material is rapidly removed by an erosive event, existing vegetation is stressed or killed, destabilizing the dune material, and resulting in shifting of the dune topography. Dune erosion can also alter the function of lenses that support dune wetlands by changing the arrangement of dune particles and changing the movement of water through the materials.

3.4.4 Bluff Erosion Effects

The properties of the rock and sediment materials forming coastal bluffs primarily control rates of cliff and bluff retreat. Bluffs made of sedimentary rocks typically erode at rates of 15 to 30 centimeters (six to 12 inches) per year (Griggs and Patsch, as cited in NRC 2012). Wave energy and impact and tidal wetting and drying processes are the drivers of erosion, and retreat of bluffs and cliffs is typically episodic, with large blocks failing suddenly under certain conditions such as heavy rainfall or large wave events (NRC 2012). Sea level rise may result in increased wave heights and more frequent large wave events, with waves breaking closer to the base of cliffs/bluffs, accelerating the rate of bluff retreat. When bluff retreat events occur, vegetation on the bluff is typically destroyed when the bluff material falls.

3.4.5 Increased Edge Effects

In addition to the habitat alterations caused by inundation, flooding, dune erosion, and bluff erosion, the lack of adequate space to retreat is anticipated to result in narrowing of coastal habitats that occur as “bands”. This narrowing increases the proportion of edge to center in these habitat units, reducing their capacity to provide certain ecosystem functions, such as shelter and movement corridors for wildlife and dispersal areas for seeds. These narrowed bands are more susceptible to disruption.

4. EFFECTS TO MORRO BAY ESHAS

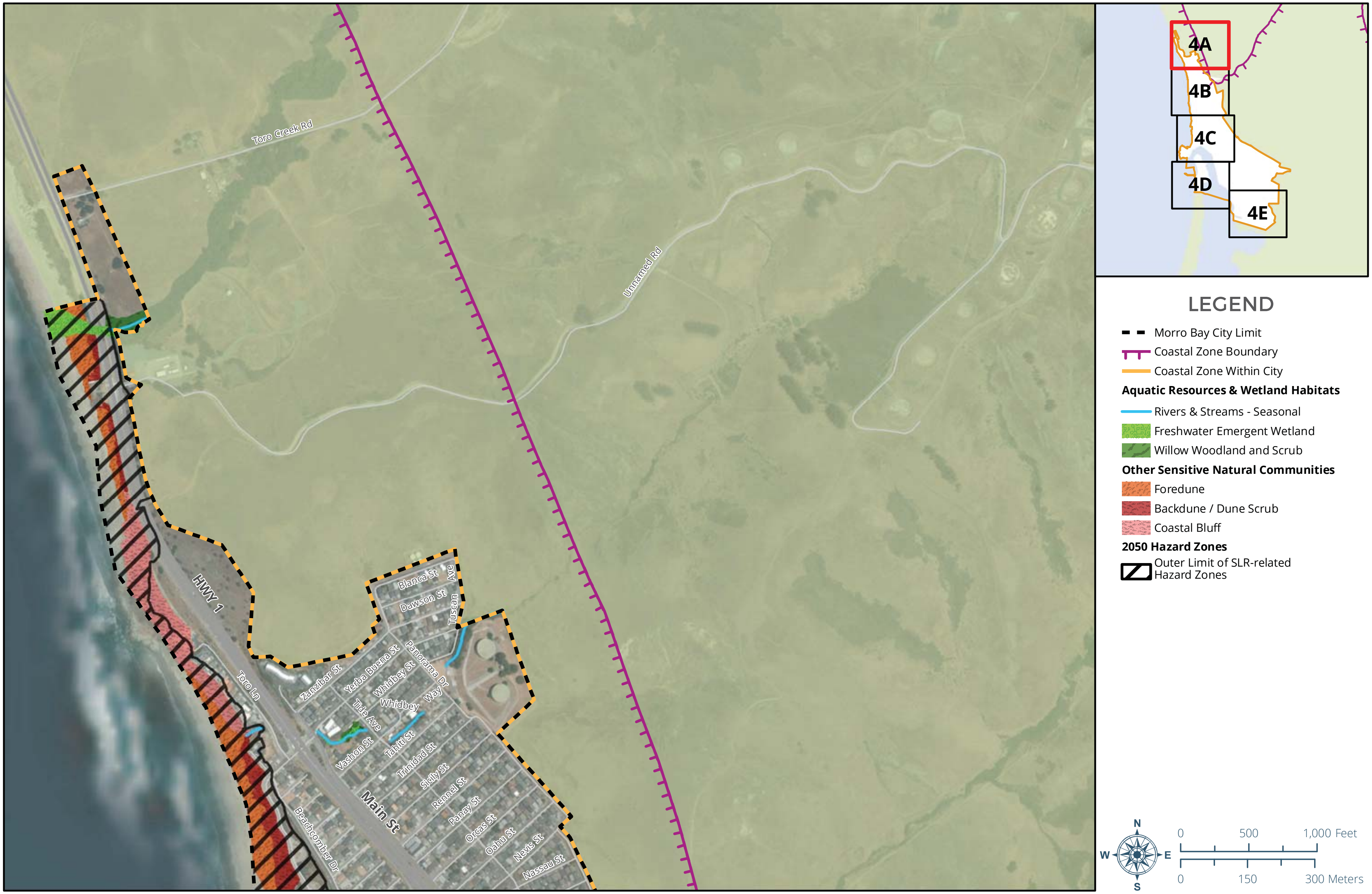
The severity of sea level rise physical effects on designated ESHAs in the Morro Bay coastal zone varies based on proximity to the high tide line, elevation of the land on which the ESHA occurs, exposure to open ocean, and sensitivity and resiliency of the community to inundation and erosion, as well as the contribution of existing stressors to habitat decline. The projected effects on each ESHA type are described in more detail below. A depiction of the maximum extent of the hazard zone types over current ESHAs in Morro Bay is provided as a map book, labeled Figures 4A-E, and Table 3 presents acreage of the total extent of potentially affected ESHA.

Table 3. Acreage of Potentially Affected ESHA

ESHA Category	ESHA Area Affected * Acres
Rivers and Streams	1.07
Willow Woodland and Willow Scrub	2.03
Estuarine Wetlands, Coastal Salt Marsh, and Pickleweed Mat	220.53
Freshwater Emergent Wetlands	1.97
Dune wetlands	6.61
Shallow Bay, Mudflat and Eelgrass Habitat	126.27
Tidal Channels	12.77
Foredune	102.58
Backdune and Stabilized Dune with Dune Scrub	29.2
Coastal Bluff Scrub	5.26
Black Hill Natural Area	0
Breeding and Overwintering Sites	2.69

**Area based on ESHA falling within a composite of 2050 sea level rise hazard zones*

Areas within these hazard zones are vulnerable to type conversion and loss. Additionally, figures depicting ESHAs vulnerable to flooding and inundation are depicted as Figures 5A-E, and ESHAs vulnerable to dune and bluff erosion are depicted as Figures 6A-D. A discussion of the types of effects anticipated for each ESHA category is provided in the following section.

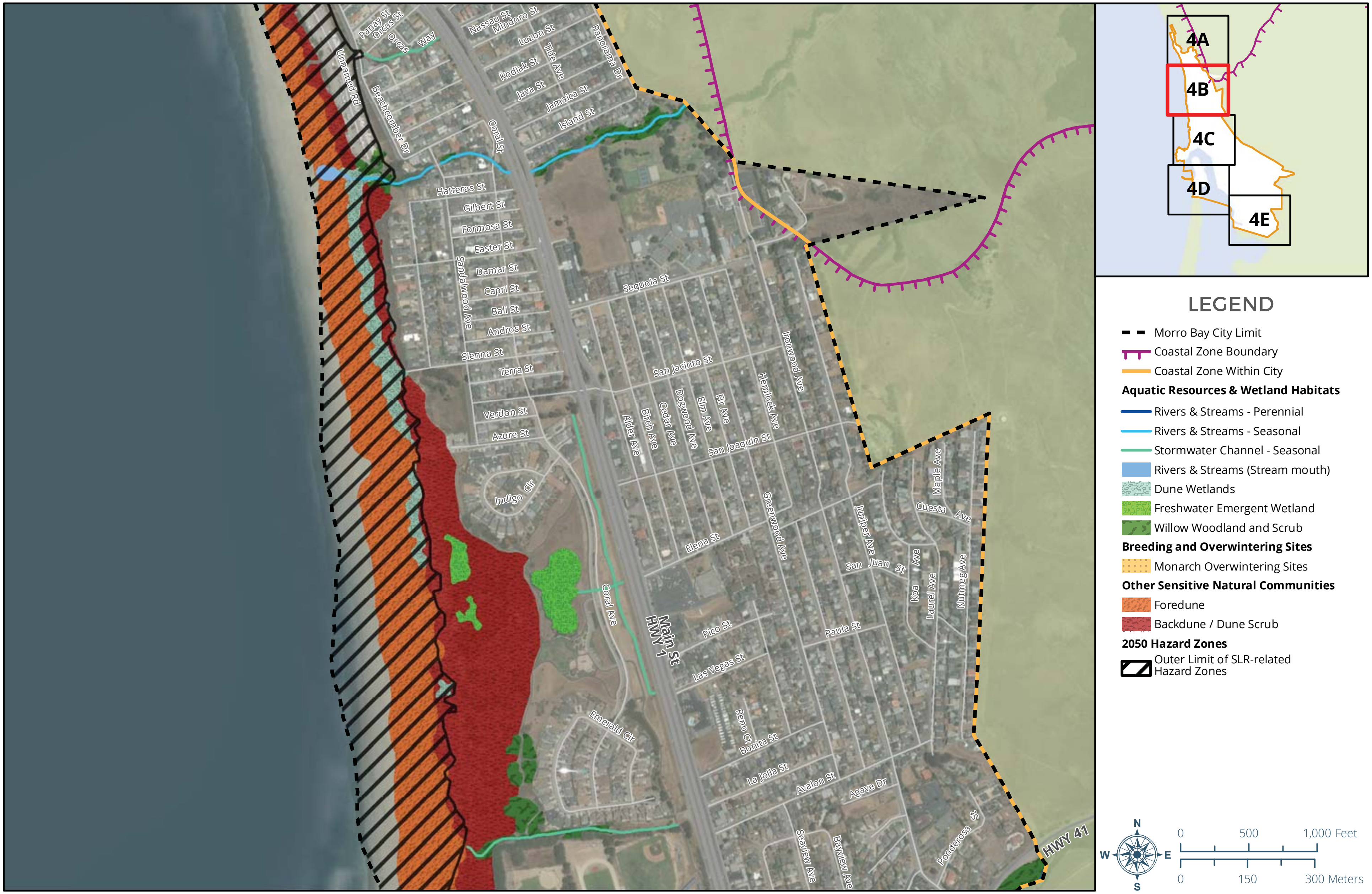


Sources: City of Morro Bay (2016); San Luis Obispo County (2016); Michael Baker Intl (2016); CA Dept of Parks & Recreation (2016); ESRI (2018).

Plan MORRO BAY

FIGURE 4A

Outer Limits of Sea Level Rise Effects on ESHA Mapbook



Sources: City of Morro Bay (2016); San Luis Obispo County (2016); Michael Baker Intl (2016); CA Dept of Parks & Recreation (2016); ESRI (2018).

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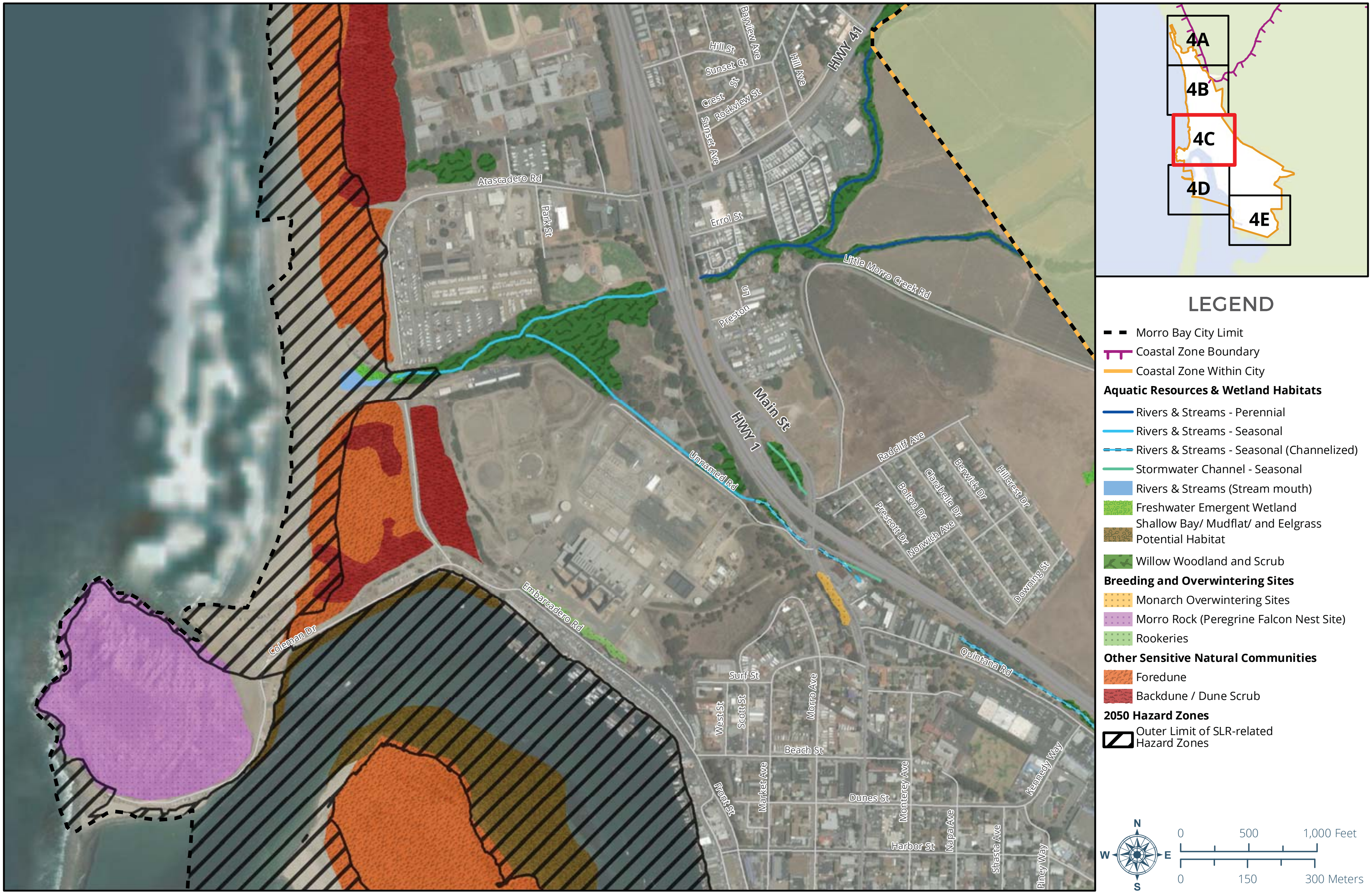
FIGURE 4B

Outer Limits of Sea Level Rise Effects on ESHA Mapbook



Sources: City of Morro Bay (2016); San Luis Obispo County (2016); Michael Baker Intl (2016); CA Dept of Parks & Recreation (2016); ESRI (2018).

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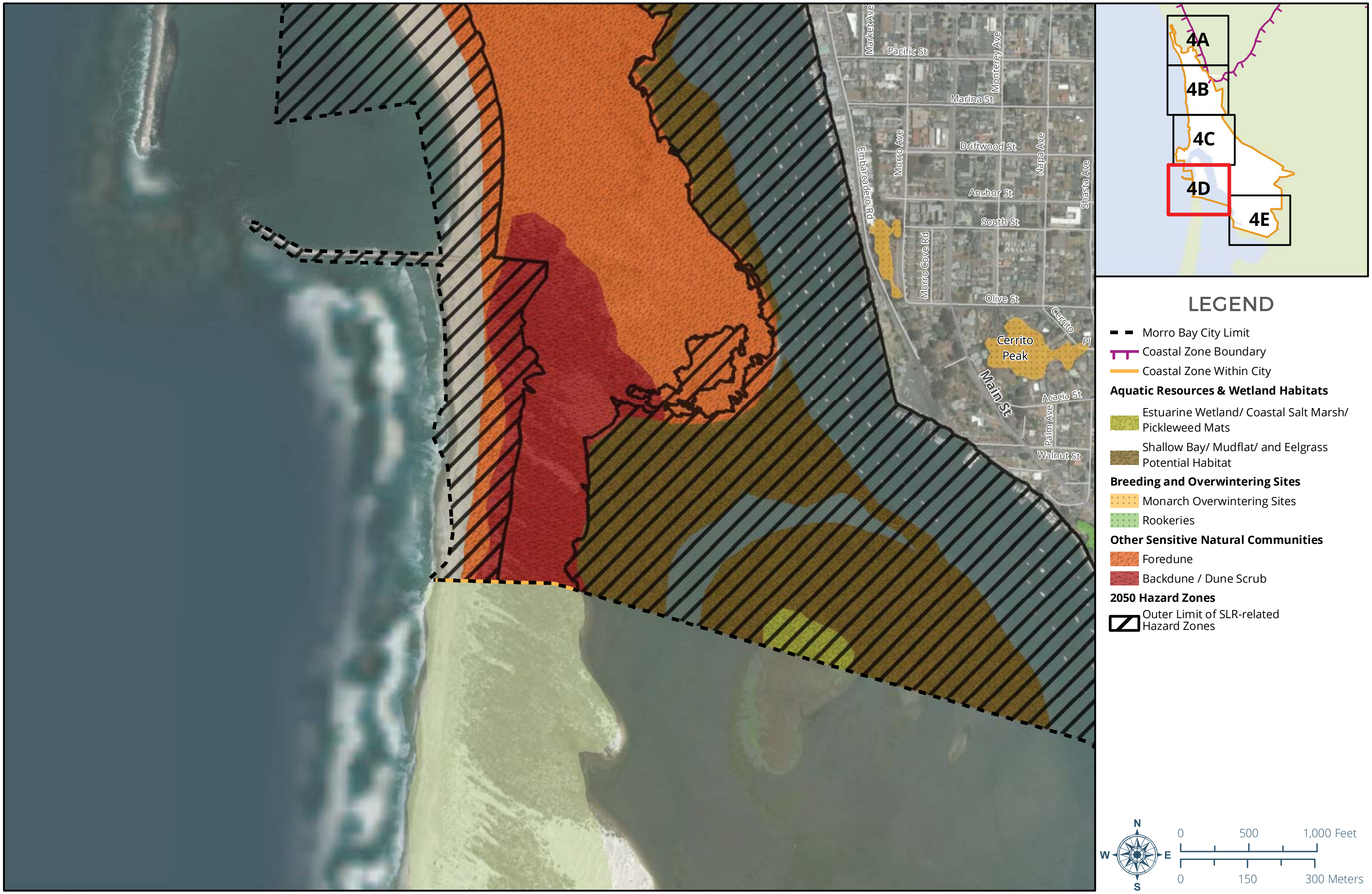
FIGURE 4C

Outer Limits of Sea Level Rise Effects on ESHA Mapbook

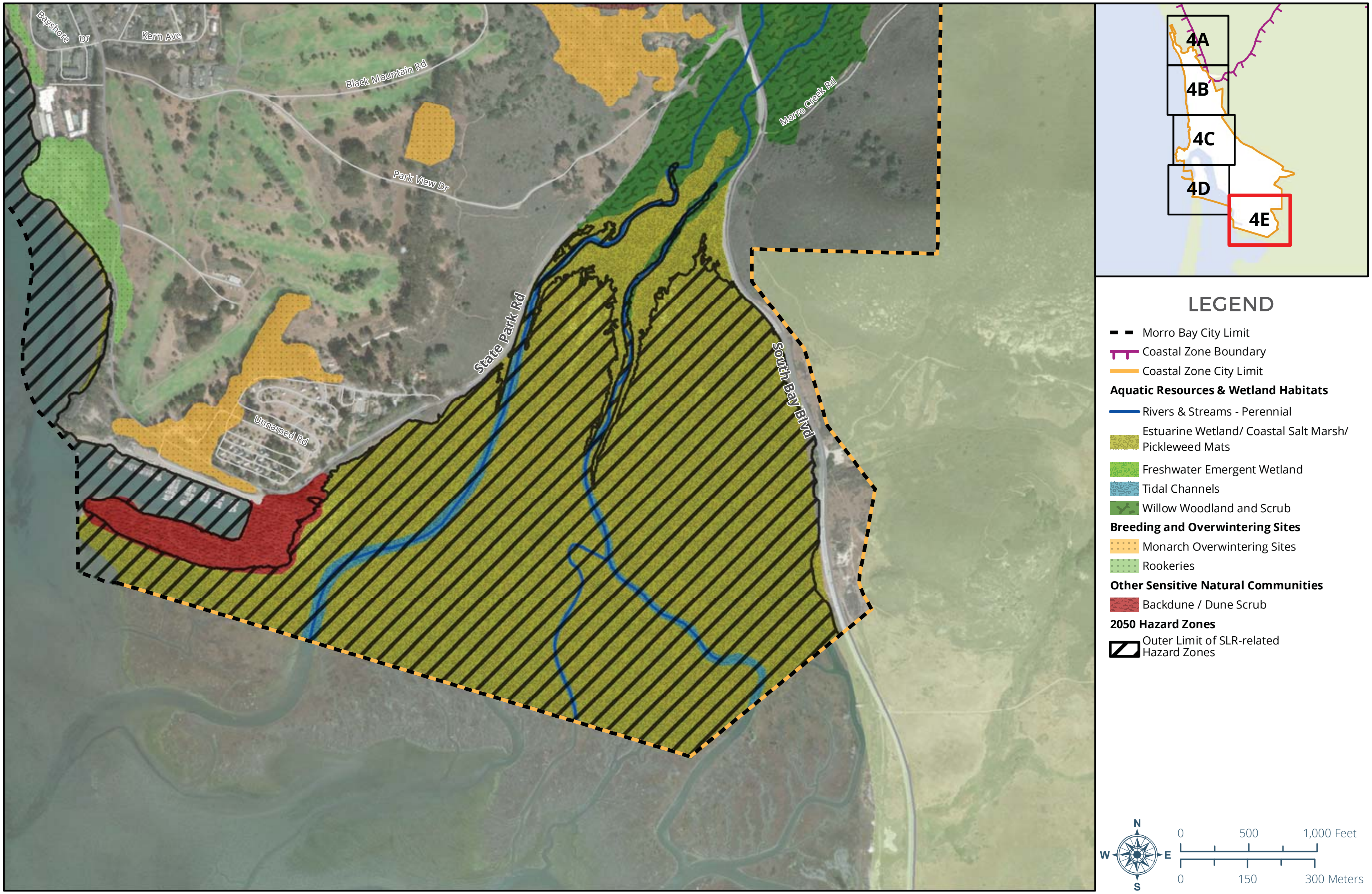


Sources: City of Morro Bay (2016); San Luis Obispo County (2016); Michael Baker Intl (2016); CA Dept of Parks & Recreation (2016); ESRI (2018).

Plan Morro Bay

FIGURE 4D

Outer Limits of Sea Level Rise Effects on ESHA Mapbook



Sources: City of Morro Bay (2016); San Luis Obispo County (2016); Michael Baker Intl (2016); CA Dept of Parks & Recreation (2016); ESRI (2018).

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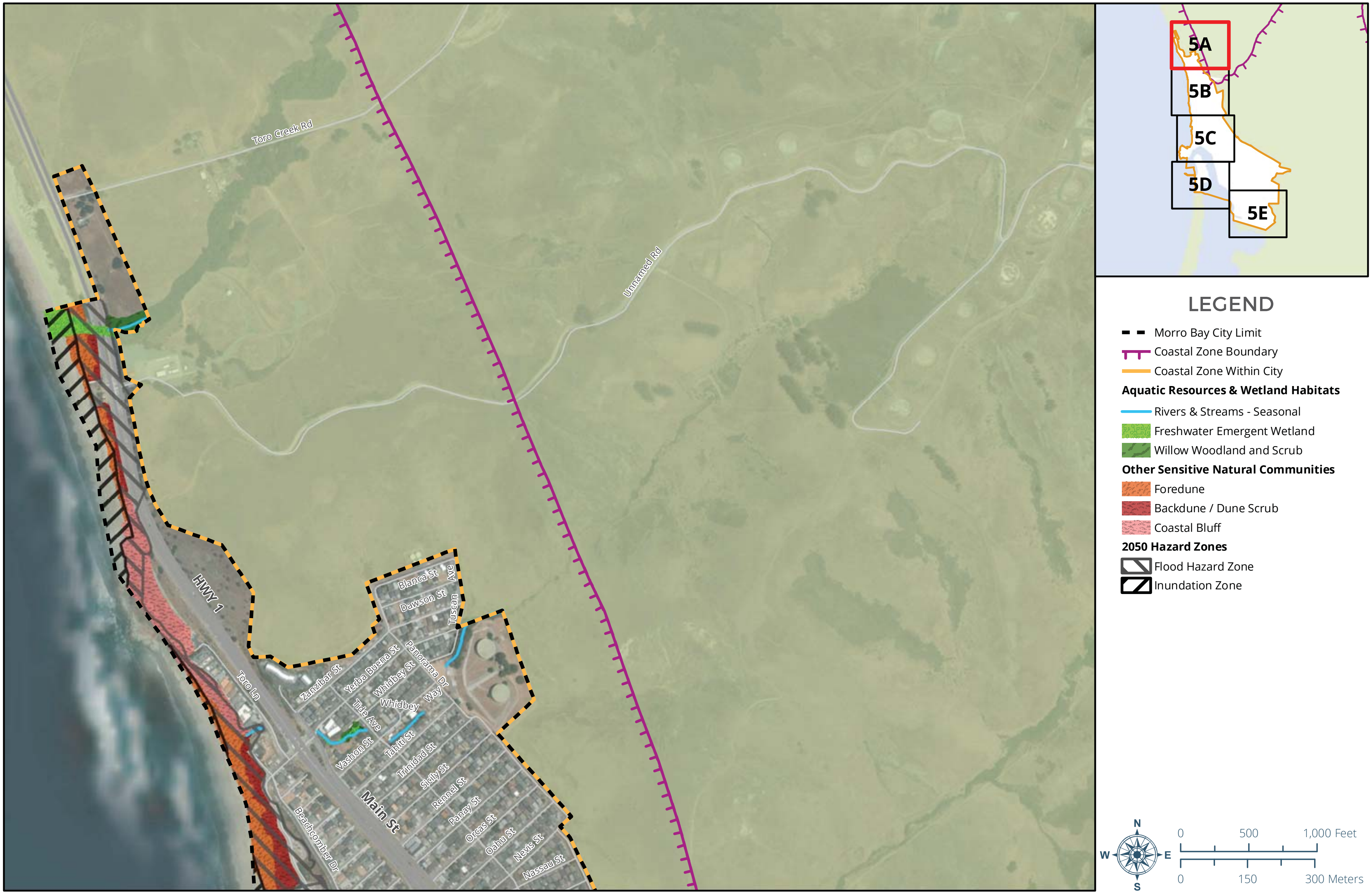
FIGURE 4E

Outer Limits of Sea Level Rise Effects on ESHA Mapbook



Sources: City of Morro Bay (2016); San Luis Obispo County (2016); Michael Baker Intl (2016); CA Dept of Parks & Recreation (2016); ESRI (2018).

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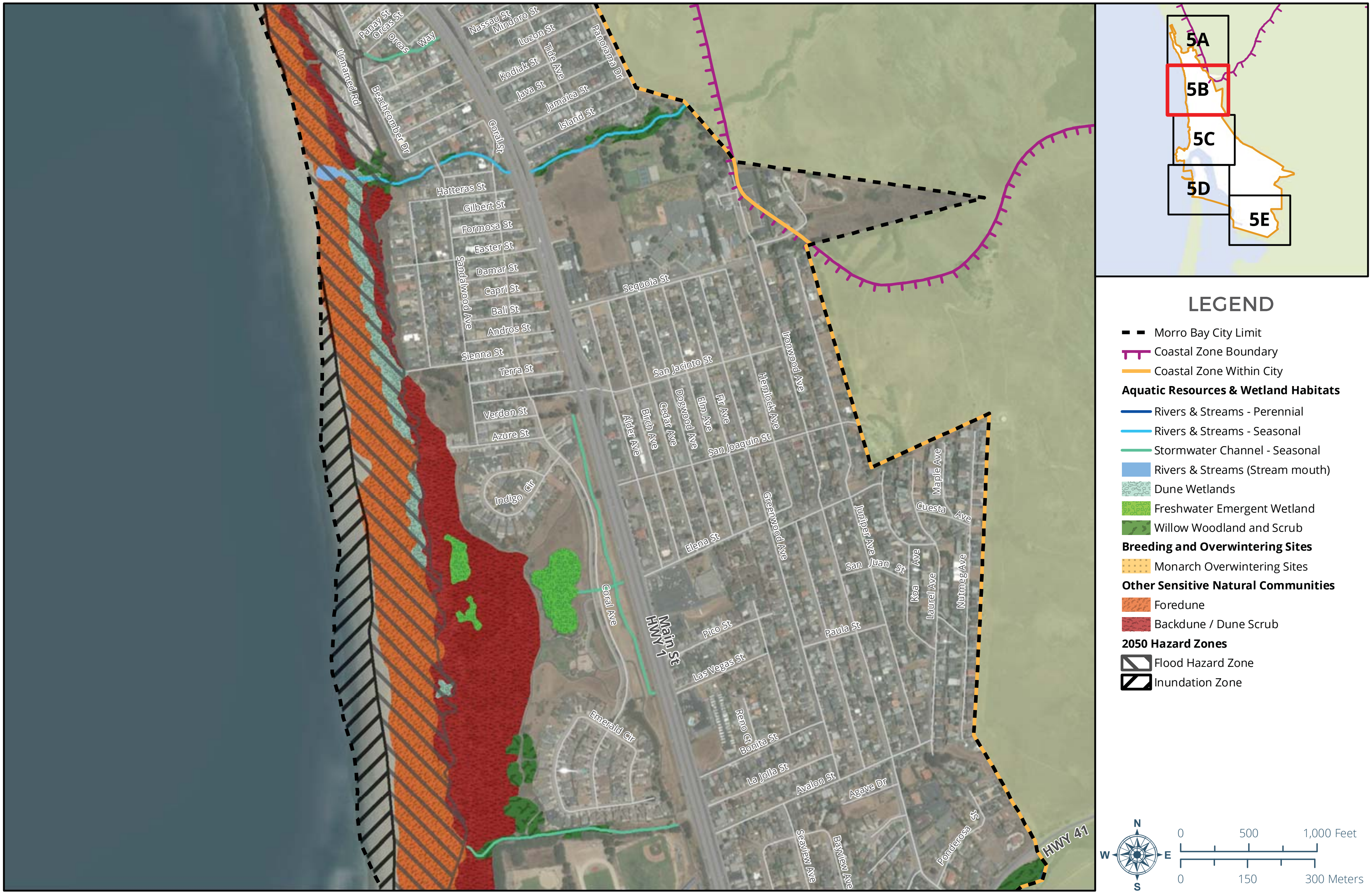
FIGURE 5A

Inundation and Flood Hazard Zone Effects on ESHA Mapbook

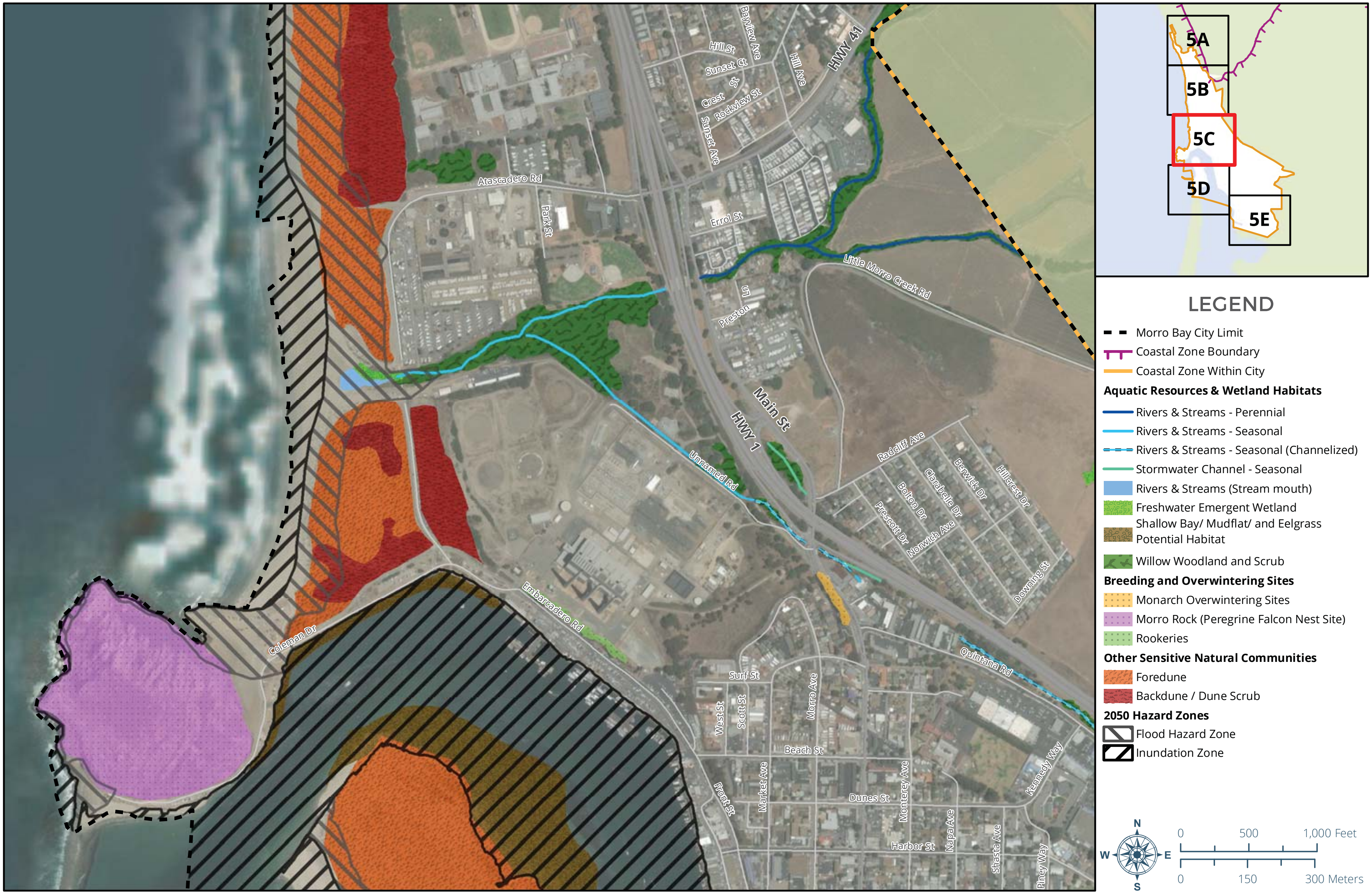


Sources: City of Morro Bay (2016); San Luis Obispo County (2016); Michael Baker Intl (2016); CA Dept of Parks & Recreation (2016); ESRI (2018).

FIGURE 5B

Outer Limits of Sea Level Rise Effects on ESHA Mapbook

Plan MORRO BAY

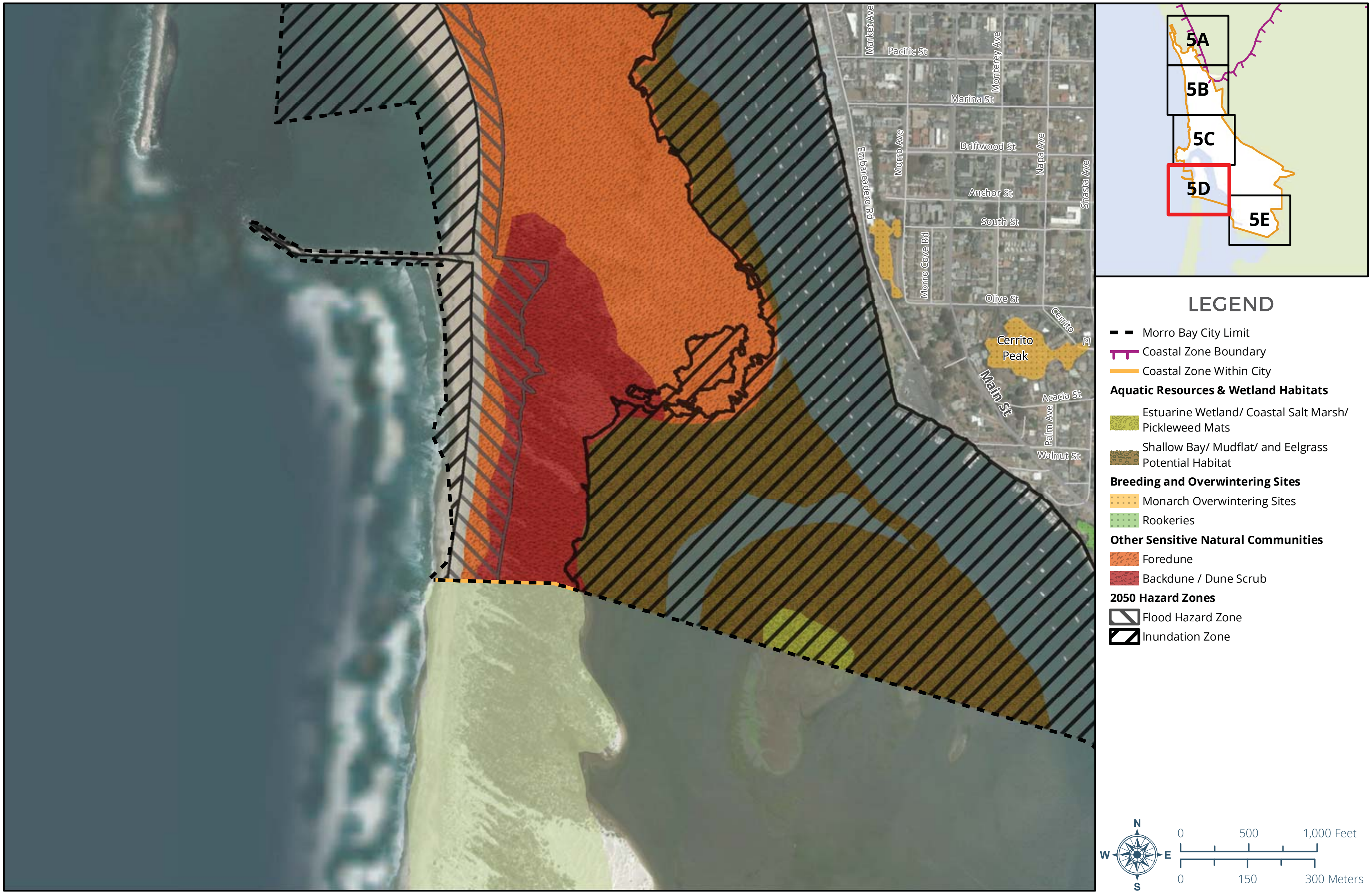


Sources: City of Morro Bay (2016); San Luis Obispo County (2016); Michael Baker Intl (2016); CA Dept of Parks & Recreation (2016); ESRI (2018).

Plan MORRO BAY

FIGURE 5C

Inundation and Flood Hazard Zone Effects on ESHA Mapbook

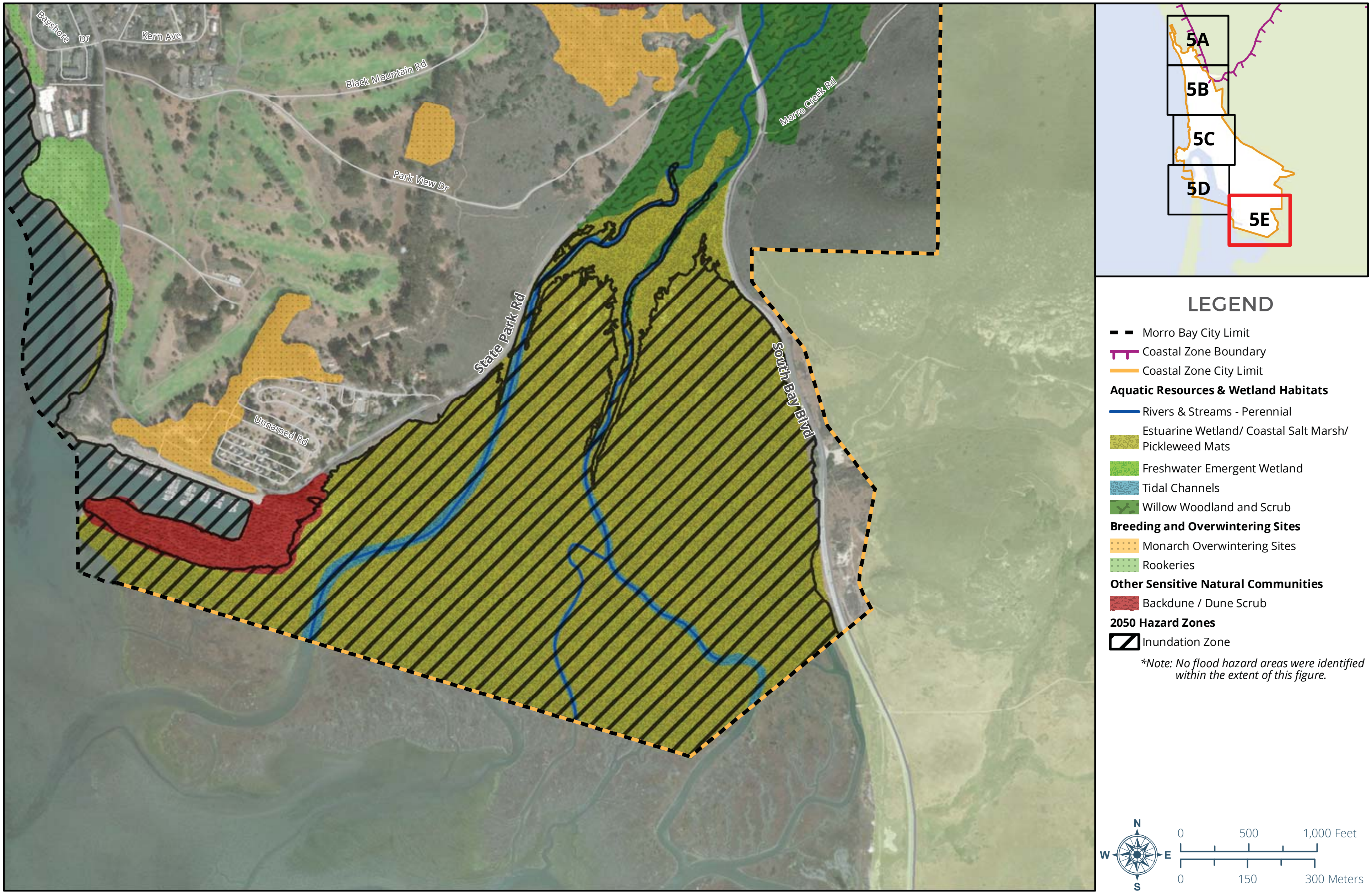


Sources: City of Morro Bay (2016); San Luis Obispo County (2016); Michael Baker Intl (2016); CA Dept of Parks & Recreation (2016); ESRI (2018).

Plan Morro Bay

FIGURE 5D

Inundation and Flood Hazard Zone Effects on ESHA Mapbook

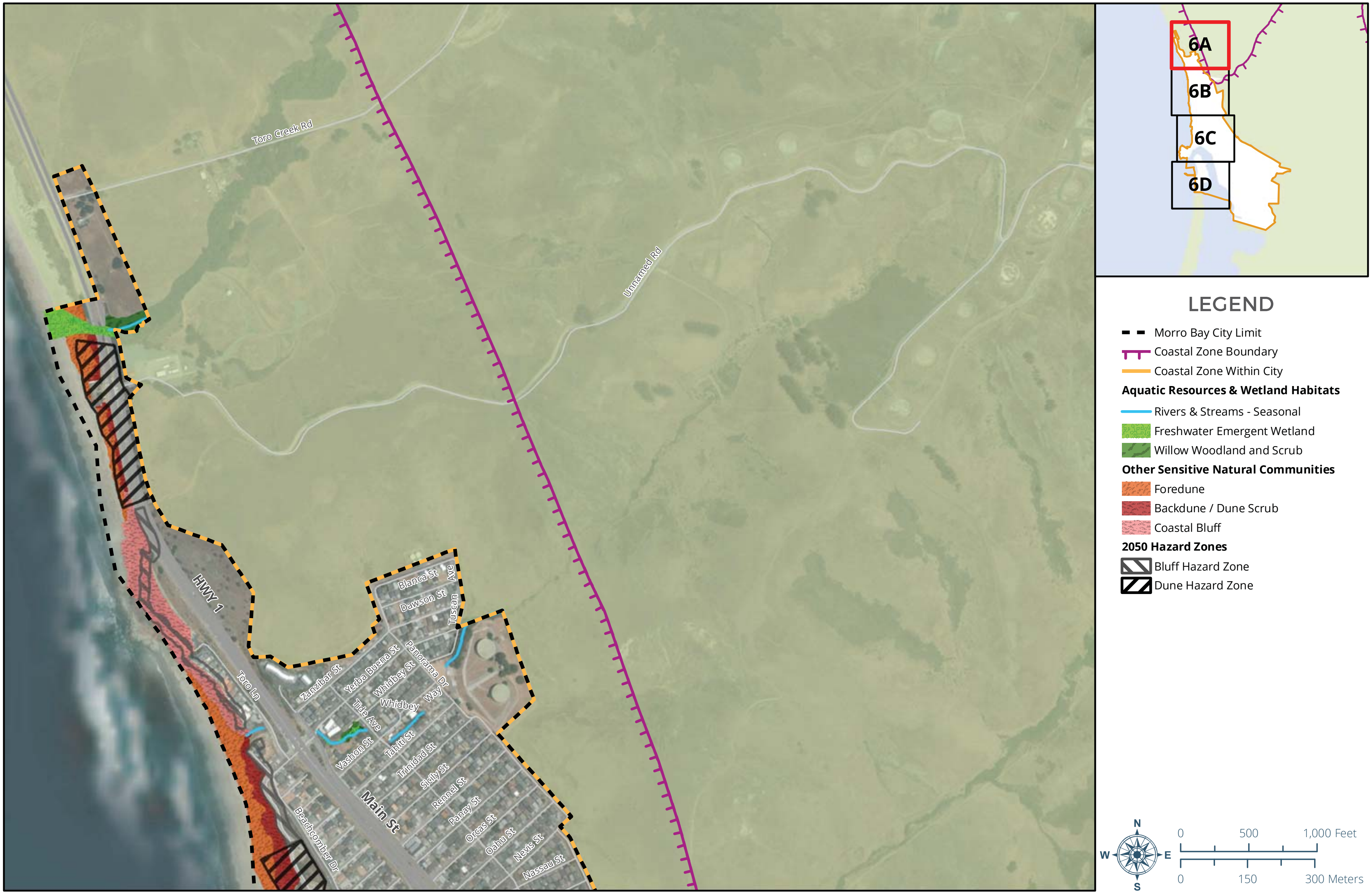


Sources: City of Morro Bay (2016); San Luis Obispo County (2016); Michael Baker Intl (2016); CA Dept of Parks & Recreation (2016); ESRI (2018).

Plan MORRO BAY

FIGURE 5E

Inundation and Flood Hazard Zone Effects on ESHA Mapbook

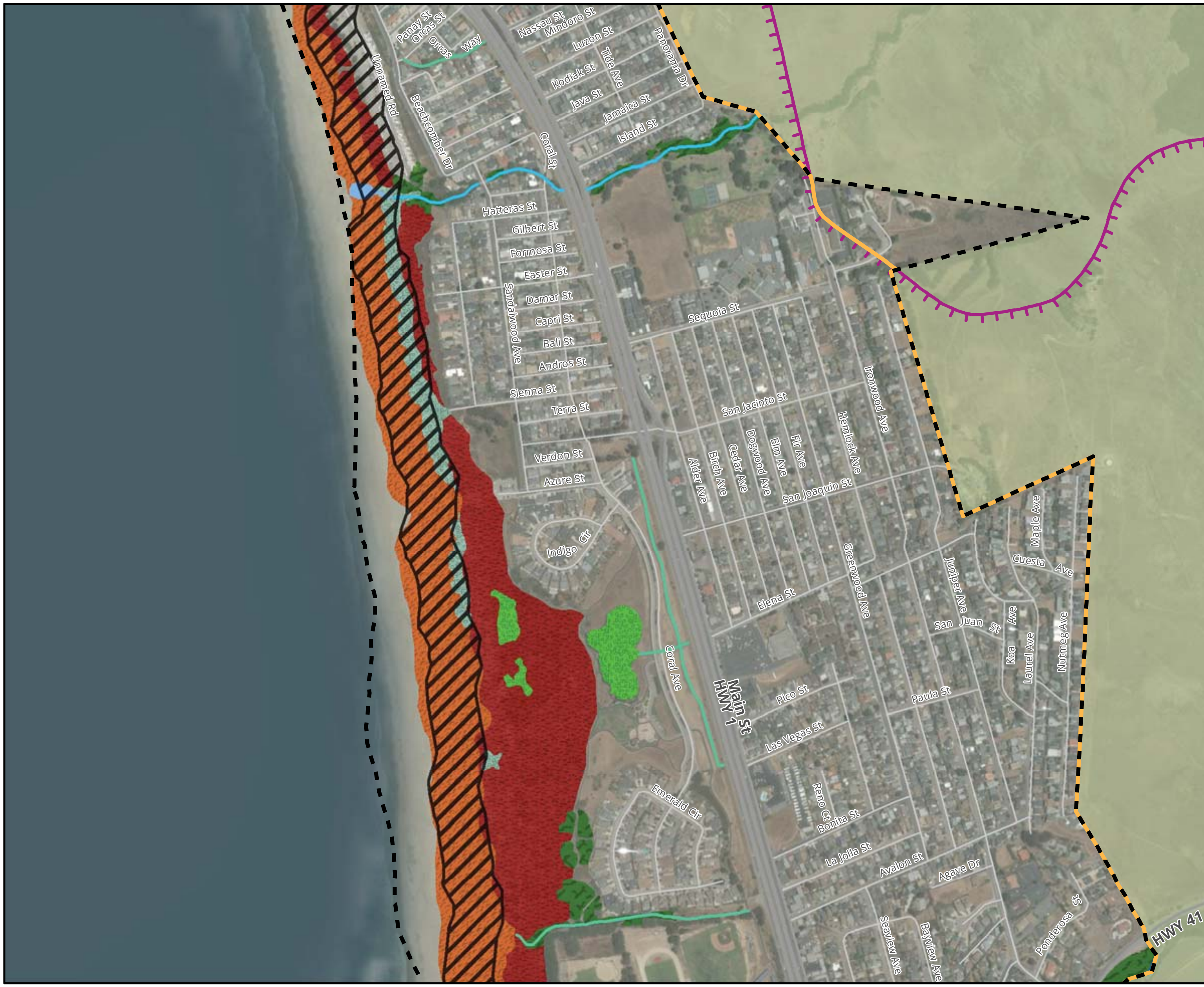


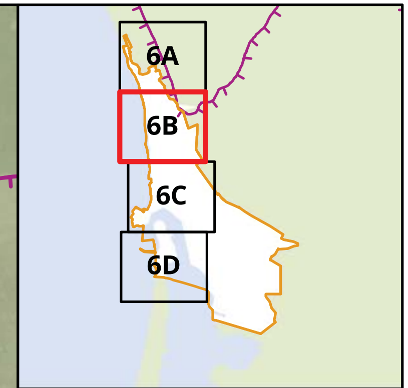
Sources: City of Morro Bay (2016); San Luis Obispo County (2016); Michael Baker Intl (2016); CA Dept of Parks & Recreation (2016); ESRI (2018).

Plan MORRO BAY

FIGURE 6A

Dune and Bluff Hazard Zone Effects on ESHA Mapbook





LEGEND

- Morro Bay City Limit
- Coastal Zone Boundary
- Coastal Zone Within City

Aquatic Resources & Wetland Habitats

- Rivers & Streams - Perennial
- Rivers & Streams - Seasonal
- Stormwater Channel - Seasonal
- Rivers & Streams (Stream mouth)
- Dune Wetlands
- Freshwater Emergent Wetland
- Willow Woodland and Scrub

Breeding and Overwintering Sites

- Monarch Overwintering Sites

Other Sensitive Natural Communities

- Foredune
- Backdune / Dune Scrub

2050 Hazard Zones

- Dune Hazard Zone

**Note: No bluff hazard areas were identified within the extent of this figure.*

N
W E
S

0 500 1,000 Feet

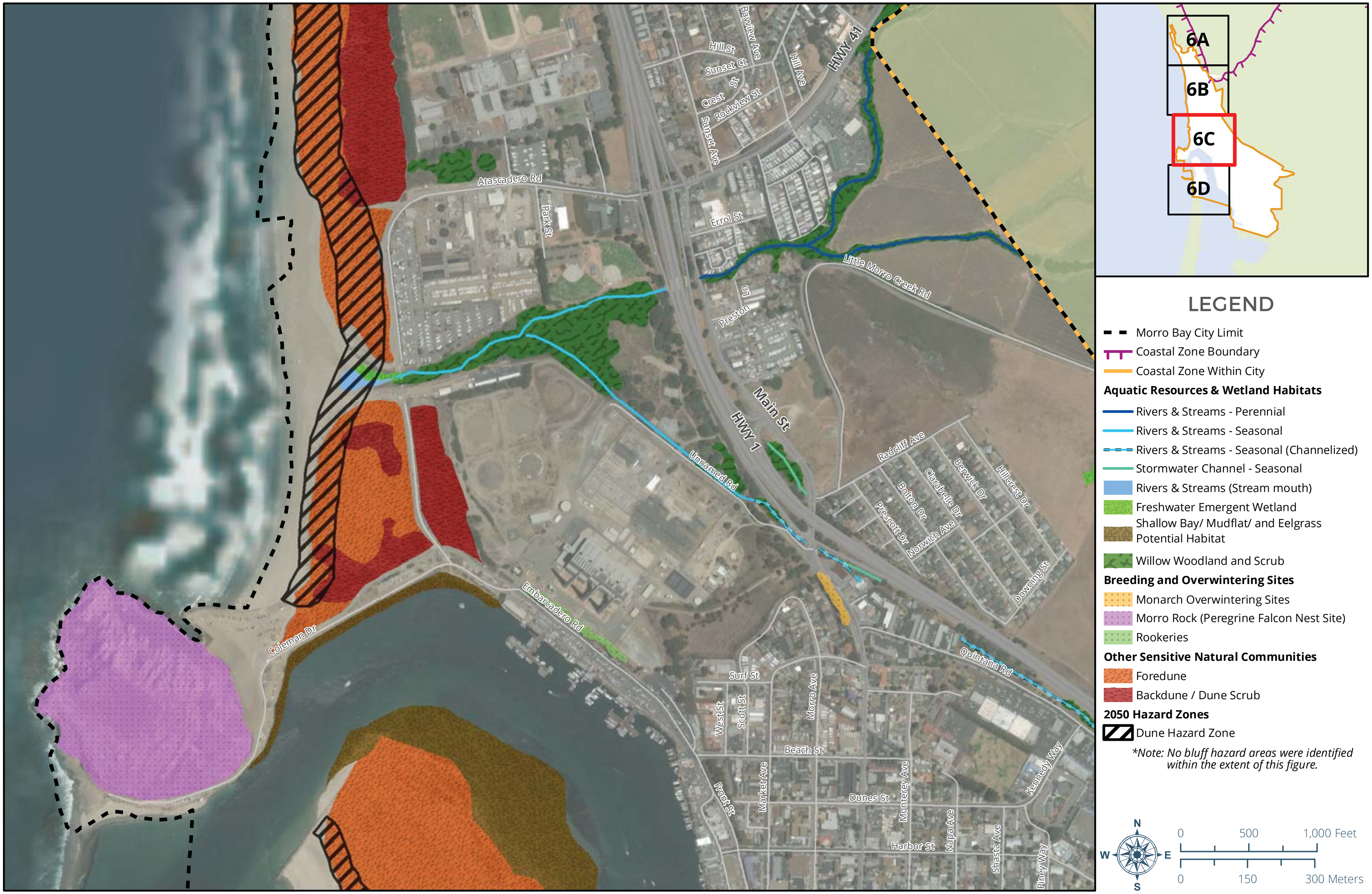
0 150 300 Meters

Sources: City of Morro Bay (2016); San Luis Obispo County (2016); Michael Baker Intl (2016); CA Dept of Parks & Recreation (2016); ESRI (2018).

Plan MORRO BAY

FIGURE 6B

Dune and Bluff Hazard Zone Effects on ESHA Mapbook

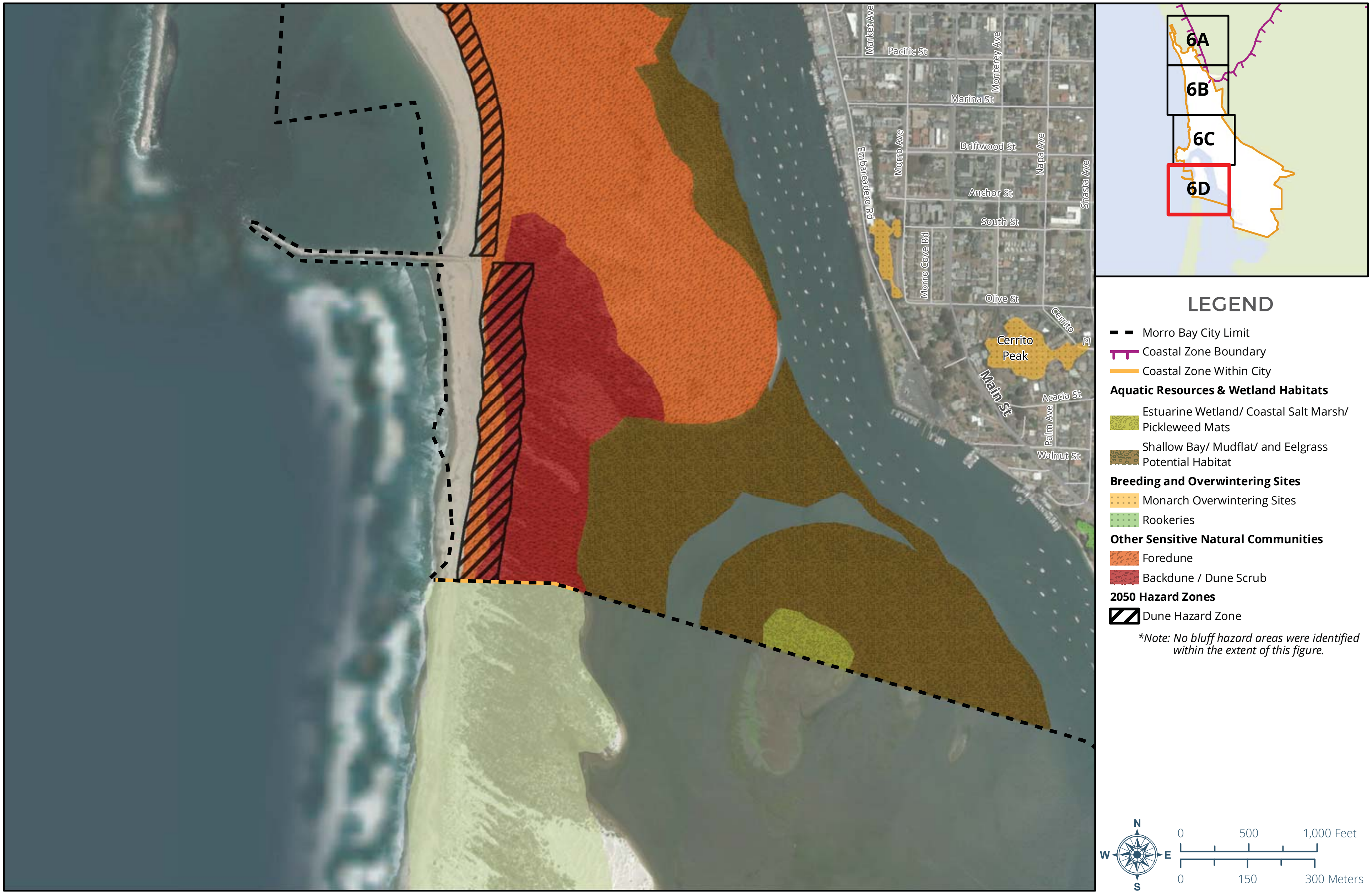


Sources: City of Morro Bay (2016); San Luis Obispo County (2016); Michael Baker Intl (2016); CA Dept of Parks & Recreation (2016); ESRI (2018).

Plan MORRO BAY

FIGURE 6C

Dune and Bluff Hazard Zone Effects on ESHA Mapbook



Sources: City of Morro Bay (2016); San Luis Obispo County (2016); Michael Baker Intl (2016); CA Dept of Parks & Recreation (2016); ESRI (2018).

Plan Morro Bay

FIGURE 6D

Dune and Bluff Hazard Zone Effects on ESHA Mapbook

4.1. AQUATIC RESOURCES AND WETLAND HABITATS

4.1.1 Rivers and Streams

Creeks and Tributaries

Effects of sea level rise on creeks and their tributaries in Morro Bay's coastal zone will be most notable at the mouths of these systems where freshwater flows out to the ocean. Higher inundation levels and increased flooding events are anticipated to result in changes to zones of saline and brackish water in small lagoons that form at the mouths of the major creeks, including Morro Creek and Toro Creek. Additionally, changes in inundation, flooding, and dune erosion patterns may alter sand bar formation, and could change the depth and location of such small lagoons. If the lagoon area is forced to retreat inland, channel geometry could constrain the feature, resulting in a smaller lagoon area.

Willow Woodland and Willow Scrub

In most areas of the Morro Bay coastal zone, freshwater riparian communities dominated by willow woodland and scrub vegetation types are upstream of areas directly affected by sea level rise and associated inundation, flooding, and erosion hazards. However, near the mouths of major creeks, including Morro Creek and Chorro Creek, sea level rise is expected to result in at least occasional increases in salinity due to increased inundation and flooding events downstream of the willows. With increases in salinity, willow-dominated communities are anticipated to retreat as such events increase in frequency to the zone in which freshwater conditions dominate.

Willow communities in and adjoining dune wetlands may be susceptible to changes in water perching patterns as shifting dunes alter lenses that perch fresh water. Additionally, flooding events may result from waves overtopping dunes that are narrowed as a result of dune erosion. Reductions in available freshwater, either due to loss of perched water as lenses are disrupted, or due to more frequent influxes of sea water during wave and/or high tide events could result in decreased vigor and ultimate death of willow plants in these areas.

4.1.2 Wetlands

Estuarine Wetlands, Coastal Salt Marsh, and Pickleweed Mat

As coastal marsh is inundated with increasing frequency, pickleweed is anticipated to become sparser and ultimately succumb to intolerably frequent submergence. Griffith (2010), BCDC et al. (2013), USGS (2016), and others have described the process through which conversion and retreat of coastal salt marsh is anticipated to occur. Pickleweed is dominant throughout the majority of the coastal marsh in the Morro Bay coastal zone, and most of this area is projected to experience inundation under the 2050 sea level rise model. While some area for retreat is available to the north near the Chorro Creek inlet, the margins of the marsh are largely constrained by rapid changes in topography and existing roads.

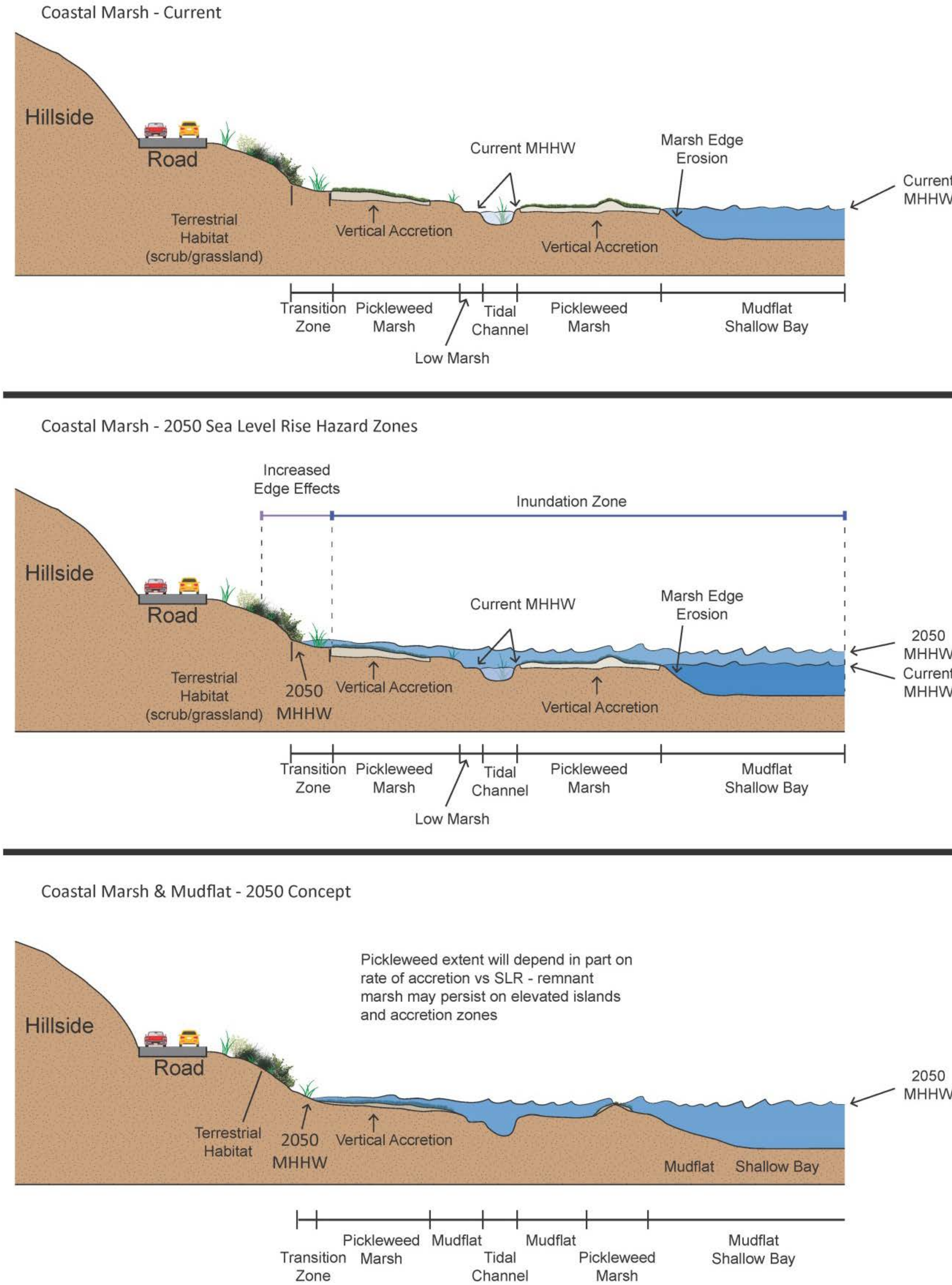
Accretion due to deposition of sediment may offset effects of sea level rise, and pickleweed is expected to persist on islands and margins of the marsh, wherever suitably elevated to meet its needs. However, accretion is not anticipated to keep pace with effects of sea level rise, and the marsh is projected to be largely converted to mudflats in the next century (Thorne et al 2018, and associated modeling). Eight National Estuarine Research Reserves are studying the placement of thin layers of sediment to supplement natural accretion processes in an effort to assist coastal marshes in keeping pace with sea level rise, but long term effectiveness and the balance of ecological costs versus benefits are not fully known at this time (Nelson 2017).

Figure 7 depicts a conceptual illustration of the processes through which sea level rise results in conversion of coastal marsh habitats.

Dune Wetlands

Dune wetlands may be susceptible to changes in water perching patterns as shifting dunes, due to erosion, may alter lenses that perch fresh water. Additionally, flooding events may result from waves overtopping dunes that are narrowed as a result of dune erosion. Reductions in available freshwater, either due to loss of perched water as lenses are disrupted, or due to more frequent influxes of sea water during wave and/or high tide events could result in decreased vigor and transition to other dune communities. Additionally, shifting sand may encroach and fill low areas that currently support dune wetlands, reducing habitat mosaic complexity in the dune system.

Figure 7. Conceptual Illustration of Processes resulting from Sea Level Rise that Cause Conversion of Coastal Marsh Habitats



Freshwater Emergent Wetlands

Freshwater emergent wetlands associated with the mouths of certain streams are expected to be affected by changes due to inundation and flooding associated with sea level rise. These factors may alter the salinity of the water and soils, resulting in a shift from freshwater hydrophytes to those more tolerant of brackish or saline conditions. Wetlands in areas of the coastal zone that are not close to the sea level rise-induced inundation and flood hazard areas are not expected to be affected.

4.1.3 Estuary and Shallow Bay

Shallow Bay, Mudflat and Eelgrass Habitat

As coastal marsh is inundated with increasing frequency, pickleweed is anticipated to become sparser and ultimately succumb to intolerably frequent submergence. This would result in conversion of areas that are presently high marsh to low marsh conditions, and ultimately to mudflat. Over the long term, sea level rise is anticipated to result in net increase in shallow bay and mudflat in the Morro Bay coastal zone. Recent modeling conducted by the USGS and UCLA resulted in similar findings (Thorne et al 2018; USGS 2016; and associated model output).

Eelgrass extent in Morro Bay has severely declined since 2007, with an estimated loss of more than 90% of the original stands (MBNEP 2017). The cause for this rapid decline is not fully known; however, it likely includes multiple factors, including increased pathogens, decreased water clarity, increased sedimentation, and excess nutrients. Because multiple factors are likely influencing distribution and extent of eelgrass in the Morro Bay estuary, the likely effect of sea level rise is unclear. One study suggests that while sea level rise may negatively affect eelgrass worldwide, in Morro Bay, bottom changes due to sedimentation may outpace sea level rise, reducing availability of suitably deep habitat in eelgrass beds (Shaughnessy et al. 2012). However, restoration efforts have been ongoing since 2012, and in 2016, some recovery was noted (MBNEP 2017). The future of eelgrass in Morro Bay is unclear, and multiple factors are likely to contribute.

Tidal Channels

Tidal channels are anticipated to persist, with greater water heights at high tide. As increased inundation results in transition of marsh areas to mudflats, it is expected that sediments may be destabilized, resulting in erosion and redistribution of materials, and potential changes to the shape and depth of tidal channels. Balancing this effect, velocities may change as a result of increased water volume and changes to sediment conditions.

4.2 OTHER SENSITIVE NATURAL COMMUNITIES

4.2.1 Foredune

The foredune community is present in the regions of unstable sand immediately adjacent to the beach/coastal strand. Due to the close proximity of these regions to the open ocean, they are the first dune ESHA to experience the physical effects of sea level rise. The foredune areas tend to be sparsely vegetated, and accelerated erosion and increased flooding hazards are anticipated to reshape the topography of large portions of the foredune. These events may interfere with reproduction and re-establishment of pioneer dune plants if the substrate is shifted too frequently, resulting in areas with greater vulnerability to erosion. Some of the area currently occupied by foredune communities will transition into coastal strand. Foredune will retreat landward to areas where pioneer plants can become established and reproduce. A band of foredune vegetation is expected to persist, but forming a narrower band than currently exists. Within Morro Bay, a portion of the impacted foredune includes the seaward side of the sandspit. Sea level rise is expected to alter the topography and condition of this prominent feature.

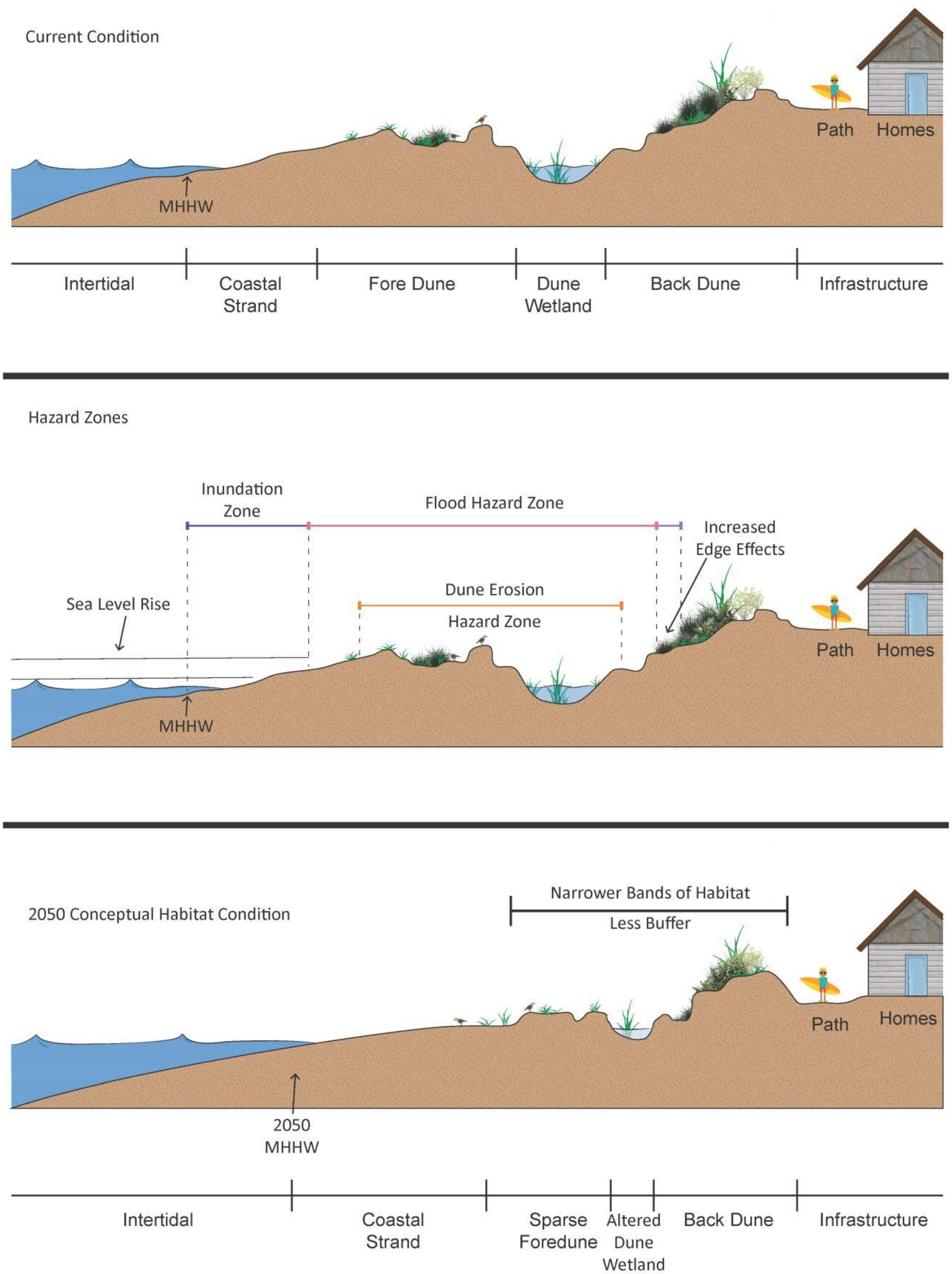
Reduction in dune habitats would also reduce available habitat for wildlife to breed, forage and take refuge. Effects to foredune habitat would thus also negatively impact the western snowy plover.

4.2.2 Backdune and Stabilized Dune with Dune Scrub

Portions of the backdune and stabilized dune areas vegetated with dune scrub are directly vulnerable to flooding and erosion as a result of sea level rise. Locations in which the bands of dune habitats are fairly narrow are most susceptible. Flooding may stress mature dune vegetation, and result in degradation of habitat. Additionally, impacts to the foredune community adjacent to the backdune, and resultant narrowing of the foredune, combined with anticipated changes to the topography of the dune area as a result of erosive processes shifting sands, are expected to result in changes to the stabilized dune. However, because these areas are well vegetated and backdune vegetation is known to catch and settle dune material, effects may be less severe in areas that currently have a broad dune system. In most areas of the Morro Bay coastal zone, the potential for landward migration is limited due to existing development and steep changes in topography.

Figure 8 depicts a conceptual illustration of the processes through which dune erosion associated with sea level rise results in conversion of coastal dune habitats.

Figure 8. Conceptual Illustration of Processes resulting from Sea Level Rise that Cause Loss of Coastal Dune Habitats



4.2.3 Coastal Bluff Scrub

Bluff scrub is limited in the Morro Bay coastal zone, and the bluffs on which it occurs are susceptible to erosion and flooding impacts resulting from sea level rise. Scrub growing on the bluff face at low elevation is susceptible to direct wave action and flooding, while scrub on the bluff top would be affected when wave action causes erosion of the bluff. Scrub species may recolonize when erosion causes material to fall as the surface stabilizes, provided the materials are not washed away. However, as the bluff recedes, the extent of bluff scrub is also expected to recede due to loss of available area.

4.2.5 Black Hill Natural Area

The Black Hill Natural Area is situated at elevations that are not anticipated to be affected by sea level rise and associated hazards within the evaluated timeframe.

4.3 BREEDING AND OVERWINTERING SITES

Currently, known breeding and overwintering sites that are not associated with sensitive vegetation communities previously discussed are situated at elevations that are not anticipated to be affected by sea level rise and associated hazards within the evaluated timeframe. These sites are primarily associated with groves of mature trees in upland landscape positions that are not currently within the hazard zones associated with sea level rise projections for 2050.

While an increased flood and inundation potential are identified around the base of Morro Rock, these changes are not expected to substantially alter suitability of the rock to support peregrine falcon breeding. Although implementation of potential adaptation strategies to protect the parking area and the barrier that protects the harbor could result in noise and disturbance in the vicinity of this breeding site, potential conflicts with nesting can be managed through strategic timing of activities.

5. CONCLUSION

Sea level rise and the associated increases in tidal inundation, coastal flooding, and dune and bluff erosion are anticipated to result in a net loss of ESHAs in the Morro Bay coastal zone, with pronounced effects on foredune and backdune communities, estuarine coastal salt marshes, stream mouths, and areas of riparian and freshwater wetland immediately adjacent to the coast. Landward retreat may occur to some extent but existing topographic features, roads, and structures limit the area available for retreat, and the expected outcome is a narrowing of the bands of coastal habitat.

It should be noted that the rate at which habitats convert to other types or are lost is not known, and although the analysis presented herein is based on a projection for sea levels in 2050, actual sea level rise could occur more quickly or more slowly than projected using current models. The magnitude of effects depends in part on how quickly and how much sea level rise occurs, how quickly sedimentation and accretion offset erosive forces, and the magnitude of other stressors on the affected coastal habitats. Habitat restoration and other interventions could partially offset effects. It should also be noted that effects of sea level rise on coastal habitats are predicted to continue beyond the 2050 horizon analyzed in this report, and longer term modeling indicates certain habitat types, including coastal marsh, may be heavily affected.

The effects presented in this report represent a conceptual analysis based on modeling and projections, and actual changes to habitat types are expected to be variable. To track actual rates of sea level rise and associated effects on coastal habitats in the City, we recommend that the City consider participating in or collaborating with existing monitoring efforts, including programs administered by the Morro Bay National Estuary Program (MBNEP), and evaluate potential new monitoring programs. We also recommend the City consider participating in evaluating pilot programs for restoration and other interventions to mitigate loss of the salt marsh and narrowing of coastal bands. Where adaptations for the protection of infrastructure are implemented, we recommend that wherever feasible, "soft" options that include habitat components should be seriously considered.

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